Examining building's energy simulation results with respect to multi-year climatic data, freely available data and climate change

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Abstract

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The main topic examined is a reference building and its energy simulations, in order to answer how the structure is influenced by climate change, which consists one of the most serious ongoing environmental phenomena in our days. It is of great importance and interest to research the impact of weather alteration on the building as years pass. To be more specific, the same building is studied for the years of 2010, 2040, 2050, 2060 and for 7 different cities all over Europe. In addition to this, different climatic sources, like multi-year climatic data and freely-available data contribute to the simulations performed, while at the same time, comparison between the results of the unlike weather sources is being conducted.

Finally, I would like to express my thankfulness to my supervisor, Mr. Theodoros Theodosiou. I wish to express my sincere gratitude for his continuous support, patience, motivation and immense knowledge.

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Contents

1. Introduction

Over the last decades, climatic conditions have significantly changed all over the world. This alteration has a great impact on the building infrastructure and, as a result, on the energy utilized to cover the respective needs. Therefore, building designers start to use promising tools in order to achieve low-energy building design. Energy simulation is an accurate approach despite the simplifications that may be made. However, climatic data are usually left unexamined by users of such methodologies, since there is no simple approximation to validate the contents of climatic data.

The aim of this study is to examine the effect of the climatic data quality on building energy simulation accuracy. This includes the construction of multi-year climatic data for selected European cities (located in the Mediterranean, in central Europe and in Northern Europe). Reliable meteorological databases and special software (Meteonorm), which is able to create climatic data files for building energy simulation software, will be used as part of the dynamic simulation approach. The above simulations will be compared to "typical meteorological years" currently used in building simulation in order to investigate the variance of the predicted results. Finally, this comparison will permit the estimation of the error created and will provide important information related to the ability of simulation to provide trustful and representative results.

2. Literature Review

In this chapter, the importance of this study is going to be determined. In other words, why should this thesis be carried out? Significant information and data will reveal the strong relationship between the climatic conditions of an area and their impact on buildings' behavior and consumption. Relevant bibliography and references are able to prove this intense connection.

2.1 Alteration of the climate

Climate change consists one of the fastest ongoing phenomena on the Earth and has a negative influence on the environment, the ecosystem, humans and economy. The evidence that the climate has changed are apparent, since the last years lay among the warmest ones on the planet. Moreover, not only the Earth's average surface temperature has risen, but also the oceans are more and more warming, leading to increased global sea level. Snow in the North and South poles is melting earlier than expected.

Why is climate change happening? Greenhouse effect resulting from anthropogenic activities is the vast cause of this state. Gases emitted directly or indirectly by people, block heat from escaping. Carbon dioxide (CO_2), water vapor (H_2O) and methane (CH_4) are some of the gases that contribute to the greenhouse effect [1]. In addition to this, temperature growth forces inhabitants to use HVAC systems, such as air-conditioners in the summer, so as to feel more comfortable. However, the usage of such systems creates a situation known as a vicious cycle. This means that the above systems emit even more heat to the environment, making it even warmer.

According to a scientific article of the European commission, the usage of air conditioning systems is going to be extremely huge in the following years due to the rapid climatic change. This is becoming a feedback source, in which energy needs and greenhouse gas emissions associated with existing HVAC systems contribute further to climate alteration and increasing temperatures. This loop is more clear in urban areas rather than in urban ones.

Another serious question to be answered is: How is climate changing? According to the Intergovernmental Panel on Climate Change: "Taken as a whole, the range of published evidence indicates that the net damage costs of climate change are likely to be significant and to increase over time". Controversial physical phenomena like intense rainfalls or storms in some areas and droughts or hot spells in others denote that climate change is patent all over the world and concerns all of us. Temperatures will continue to rise, hence humanity ought to find a solution to mitigate this situation and cope with it.

2.2 Buildings energy efficiency and climate change

Whether the alteration of the climate is inseparably linked with the infrastructure and the energy consumption needed to preserve it or not, is a subject for discussion. Scientists sound the bell that buildings are unable to keep up with the rapid change of the climate, leading to reduced thermal comfort conditions and fuel poverty. It is true that the relationship between the building sector and the energy consumption is a two-way process. Buildings contribute to climate change with their gas emissions while, at the same time, climate change forces the utilization of additional HVAC systems for the continuously increasing cooling needs.

To be more specific, burning fossil fuels for electricity, heating and cooling immediately underwrites the fact that building energy consumption affects the climatic transformation procedure, since the exploitation of fossil fuels releases gases to the atmosphere. In reverse order, existing buildings must adapt to a new, warmer environment, since temperatures are rapidly increasing. Buildings in Northern countries start to suffer from excess thermal insulation, which leads to overheating.

A case study carried out in the Netherlands underlines the necessity to meditate the effects of climate change in dwellings. Overheating outcomes start from thermal discomfort conditions and may lead to dangerous situations such as illnesses or even death. The above paper aims at studying the risks of overheating in existing and new building stock, which are linked with climatic data scenarios and their intensity. The scenarios are the following:

Average, Extreme, Future, and Worst Future [2]. Climatic data are selected from the Royal Netherlands Meteorological Institute and the overheating risk in thousands of dwelling cases is studied. Also, the buildings were constructed from 1964 to 2012 and their status present 9216 possible configurations of design and operation parameters [2].

The results of the above case study are the following [2]:

- Old buildings with little or no mechanical ventilation are at risk of overheating
- Dwellings with higher solar heat gains and lower heat transmission are at high risk of overheating
- The Dutch dwellings with minimum ventilation rate are already vulnerable to overheating and this is expected to get worse as global warming continues
- Depending on the building design and the operational parameters, the overheating escalation factor varies
- For a given climatic scenario, there is a significant difference in overheating risks in dwellings and the differences will increase in the future as global warming continues
- Adaptative measures to global warming are ventilative cooling and solar protection

It is apparent from this case study that climate alteration and global warming studied with different climatic data conditions result to overheating issues, mostly in Northern countries that are not used to such conditions, like the Netherlands. The most sensitive dwellings are those that have no protection against the sun such as good ventilative cooling options. The Dutch government should act immediately, in an effective way so as to mitigate the overheating of the buildings.

Another case study carried out in Turkey investigates the heating and cooling requirements in existing and new built apartment blocks. The study is based on the projected impacts of climate change for three different cities: Ankara, Istanbul and Izmir. Parametric analysis is done representing cold, temperate-humid and hot-humid climatic conditions. In Turkey, regional differences in climatic conditions exist because of the complex topography. Research is limited with three of the most populated cities of Turkey. The biggest city is Istanbul, which represents temperate-humid climate. Ankara is the second biggest city representing cold climate and Izmir represents hot-humid climate region [3]. An existing apartment block is modeled, in order the predictions and simulations of the various scenarios to be investigated. The block was built in 1990, when the national regulations did not force building thermal insulation applications, hence the building is poorly insulated.

Cooling demand in existing apartment blocks is more than in the newly-built apartments, with the percentages of 56.5 in Ankara, 37.6 in Istanbul and 30.6 in Izmir [3]. Due to global warming is obvious that the cooling needs are increasing compared to the heating ones. In addition to this, the rate of the cooling demand varies according to regional climatic features. For example, cooling energy demand in a hot-humid climate (Izmir) is higher than in other climatic regions. As a result, for a hot-humid climate four times more energy is expected for cooling needs in 2080, whereas in a temperate-humid climate, this increase may be 10-times more [3].

The final results of the case study are summarized as follows:

- Heating and cooling energy demand in existing apartment blocks is higher compared to the newly built dwellings
- Though the climate in Turkey is expected to warm up, heating requirements are still higher than cooling ones in the building sector
- Cooling needs are expected to increase much more than the decrease in the heating needs
- There is necessity of passive cooling strategies such as natural ventilation and shading as well as thermal insulation as far as the old building stock is concerned

This study makes clear that the majority of the building stock in Turkey is insufficient and vulnerable towards the upcoming consequences of climate change and global warming. It is common that engineers design based on past statistical climatic values. However, outdoor climatic conditions are rapidly changing .Therefore, buildings designers should re-examine design criteria related to climatic data, especially for summer months.

According to a scientific article of the European commission, the impact of climate change on indoor conditions has been extensively studied, but few have compared its consequences on different types and ages of buildings as a part of parametric analysis. The engineers simulated the following four building types in Vienna: pre-World War I, post-World War II, 2000 onwards and highly glazed (buildings clad with a glass exterior) and 2000 onwards built to low-energy passive house standards [4].

Heating and cooling demands for the recent past, the present and the future were calculated with the help of special simulation tools, based on multi-year and freely available data, taken from three different weather stations in Vienna. The buildings simulated were of different construction and operation, however the same schedule was considered for simplification reasons.

The results showed that between 1960 and 2050, the net energy cooling demands of all four building types increased constantly [4]. The highly glazed and passive house types had the highest cooling demands. Houses in the city center as well as those facing the West appeared also high cooling needs, fact that denotes how significantly the location affects the results in heating and cooling simulations [4].

Dangers and effects of the ongoing phenomenon of climate alteration in comparison with the existing infrastructure is the matter of subject of many studies. *Such a study has been conducted by Santamouris, Asimakopoulos, Farou, Laskari and Zannis concerning the building sector of Greece.* To start with, buildings live for many decades and have high initial cost. In addition to this, the owner is obliged to pay for every single miss that may occur during its duration of life. As far as its energy demand is concerned, the storyline is exactly the same. If the house is not originally energy designed, the owner has to afford paying an expensive, non- environmentally friendly residence for a lifetime [5].

Greek buildings, in general, present high energy consumption rates. According to Eurostat and the European Center of Environment, they lay among the ones with the greatest energy consumption values. In particular, energy consumption of households in Greece is as twice as the one in Portugal, whereas at the same time, households in Spain seem to spend 30% less energy than those in Greece [6]. This fact has dramatic consequences on the energy balance of the country and affects the economic sector, as well.

Taking into account that energy demand is immediately connected to climate, climate change provokes vast consequences on the whole building sector [7]. Urban heat island phenomenon is apparent in big cities of Greece and is due to different thermal characteristics of materials that prevail in cities, compared to the physical characteristics of the environment. Especially, a study conducted for the city of Athens shows the following results [8]:

- Of the total of 274 days with maximum temperature >37^{o} in 150 years, 129 days were noticed during 1998-2007
- Of the total of 42 days with maximum temperature >40^{o} in 150 years, 20 days were noticed during 1998-2007
- Of the total of 52 incidents of heat waves (with maximum temperature >37^{o} for more than three continuous days) in 150 years, 19 of them were noticed during 1998-2007

The necessity of immediate acts, as far as the energy consumption of buildings in connection with the environment is concerned, is obvious. Some of the measures that have to be taken are the following: reduction of carbon dioxide emissions from buildings, enhancement of inner environment, invigoration of the structural field, incorporation and usage of renewable energy sources in the building sector. Santamouris, Asimakopoulos, Farou, Laskari and Zannis have conducted simulations as far as useful energy demand in the building sector is concerned.

There are four scenarios used: the optimum one, the optimistic one, the realistic one and the catastrophic one. The first one supports that even though there is great climate alteration, energy consumption of buildings could be reduced to 5-10000 GWh by 2050 if people use modern energy technology for energy production in all buildings. The second scenario (optimistic) says that energy demand will be reduced to 22000/25000 GWh/ year by 2050, if buildings are energy designed with high- efficient systems. Realistic scenario says that if 70% of all buildings in Greece incorporate high-performance systems by 2050, then whole energy demand will be reduced to 50000/55000 GWh/ year. Catastrophic scenario supports that only 10% of existing buildings will manage to set up energy systems by 2050, so energy demand will overcome 120000/130000 GWh/year [8].

The results of the above scenarios are used in order to calculate extra costs that come from the adjustment of HVAC systems in buildings. The percentage of extra costs that the building sector is burdened because of climate change varies between 7.6% and 10.3% of the overall renovation costs, depending on the area. The mean value of the country is approximately 9%, which means that the additional expenditure that climate alteration is going to provoke on buildings until 2050, is estimated by 20-21 billion Euros.

2.3 Climatic files and their importance

Climatic files are of great importance, since climate change is a rapidly changing process. The best available information should be utilized, so as future weather conditions to be simulated or predicted. As far as the building sector is concerned, climatic databases are crucial because dwellings are constructed for at least 50-100 years. As a result, the structure has to behave functionally not only in the early years of its construction, but also in the future. Consequently, weather files that any study is based on, affect the whole lifetime of the building and they are complex with long-term implications [9].

The historical, contemporary, and future consequences of the climate are vital, therefore empirical research has been done in order to conceive how the weather behaves and changes. In the last few years, new studies using panel methodologies, year-to-year frequencies, alterations in temperature and other climatic variables identify such changes [10]. The importance of weather files, their correct research and utilization gives reliable results in the energy, economy, building and other sectors. As already mentioned, building energy consumption is highly dependent on weather files, however climatic data files sometimes are abstract and not site-specific.

A study made by Carlo Bianchi, Stephen M. Lucich, and Amanda D. Smith researches the influence of weather boundary conditions on buildings. In the above paper, the influence of weather boundary conditions on energy simulations for four commercial building types, which are located in the U.S.A, is investigated [11]. The study is conducted with the help of Energy Plus and building models.

The buildings studied are: a small office, a hospital, a primary school and a restaurant. They are chosen because their types are different, so there are variations in the loads. As far as the energy consumption is concerned, the hospital and the school are mostly occupied by people, so the electric load is very high, whereas for a restaurant the heating load is the prominent component. In addition to this, it would be very interesting to study the above with the weather location being a parametric clue. The weather data for the simulations are taken from Typical Meteorological Year files [11]. The most updated version is the TMY3 that contains 1400 sites in the States. These files are compared with weather data taken in 2012-2014 at two other weather stations located in Salt Lake City: WBB (William Browning Building, University of Utah campus) and OLY (Sterling Benefits Insurance Services building, near Olympus Hills) [11]. The above three data sets comprise the boundary conditions for the study so as to predict and analyze the influence of different weather conditions.

The results showed that electric loads are negligibly affected by the weather boundary conditions, however when the climatic input files change, the results of the heating loads are highly influenced. However, it is not possible to predict if the changing attitude of the heating loads is influenced by the different locations or because of the year-to-year different conditions.

According to a research that studies the development of climate change adapted weather files for building performance simulation and the implications for Southeast Asia, modern weather files used for simulations are typically derived from historical weather data of the time period 1961-1990 [12]. This is definitely a great disadvantage for present simulations, since nowadays weather trends have suffered from great transitions. The above situation undergoes the risk of constructing unreliable, inconvenient buildings that cannot anticipate the latest evolutions.

There are various tools that users can rely on in order to predict the expected weather conditions. Some of these tools are Energy Plus or Typical Meteorological Year (TMY) and they are essential for sizing HVAC systems prior to construction. Statistical analysis based on historical datasets is necessary. From the above study, it becomes evident that as far as Southeast Asia is concerned, modern building design projects are based on climate change adapted versions of weather files. It is important so as to evaluate the building's potential future performance and dimension HVAC facilities in an accurate way.

Another study presented in the 9th International Conference on Sustainability in Energy and Buildings in Crete, Greece, underlines the effect of weather datasets on building energy simulation outputs. The study starts with three points that negatively influence the simulation modeling procedures. These factors consist of the inefficient characterization of operational schedules, the limitations in the simulation algorithms, the quality and reliability of data contained in weather files [13]. The last aspect appears to be the most limiting and uncontrollable one, since the user cannot regulate the historical and statistical sources. In addition to this, statistical analysis always contains abstract meanings like possibility or uncertainty.

The above research refers to a public social housing block located in the city of Milan, having different weather files as the parametric clue. The public social housing block consists of two L-shaped buildings with four stories each and a total of 66 flats, most of which were built in the 70s or 80s [13]. The work summarized in the paper, focuses on the effects that an insufficient weather dataset has on energy simulations, which should be compatible with the latest local climate alterations in order to be trustworthy [13]. Various weather datasets have been used in order to provide information to the simulation model, some of which have been developed with the help of data gathered between the 1950s and 1970s [13]. The necessary parameters able to run the above simulations, such as relative humidity or dry-bulb temperature, are based on hourly values provided by the weather datasets.

The paper showed that the choice of an appropriate weather dataset is crucial as far as the energy savings and thermal comfort conditions are concerned. The results of the study clearly report that there is an essential yearly increase of cooling needs. Finally, future weather scenarios are quite similar to projection for 2080, however they rely on the quality and reliability of the datasets as already mentioned [13].

3. Methodological Approach

This section is focusing on the methodology followed so as to achieve the goal defined. Not only dynamic simulation tools like Energy Plus, but also special software like Meteonorm, which creates stochastic climatic data, is being used. The targets of building thermal simulation are the calculation of loads and energy analysis. In general, simulation is important, since buildings consume approximately the one-third of all the energy consumed nationally every year [14]. It can also become the key factor in reducing the energy consumption of buildings.

3.1 Program of EnergyPlus

According to the official webpage of the program: "EnergyPlus is a whole building energy simulation program that engineers, architects and researchers use to model both energy consumption-for heating, cooling, ventilation, lighting and plug, and process loads-and water use in buildings."

It is, in other words, a fully integrated building and HVAC system simulation program. Its central scope is to equip the occupants with a thermally comfortable environment, since it provides heat balance load calculation, moisture balance calculation, simultaneous system solution and HVAC system simulation [14]. Many confuse thinking that it is a design program or a Cad system, but it is not. Also, it is not a user interface or a life cycle cost analysis tool [14].

EnergyPlus has many capabilities like:

- Integrated, simultaneous solution
- Heat balance based solution
- Sub hourly, user definable time steps
- Combined heat and mass transfer
- Advanced fenestration models
- Glare calculations
- Component based HVAC

- A large number of built-in HVAC and lighting control strategies
- Functional Mockup Interface
- Standard summary and detailed output reports

EnergyPlus provides all the information needed through the known called "libraries", or in other words Datasets. Both flavors of Datasets (simple and macro) contain IDF objects ready to be put into EnergyPlus input files [14]. The main difference between the above flavors is that in the first one (simple) the programmer has to use a text editor or the IDF editor to search the file needed. On the other hand, macro Datasets with the help of an imf (input macro file), give the possibility to the user to name the item needed to be included [14]. In general, EnergyPlus has the possibility to convert the older files into newer versions. If the older version is from the previous release, the pull-down file menu and the order "transition" can achieve this variation. If the older version is older than the previous release, then downloading multiple transition program is essential.

As far as the locations and design days are concerned, the file Locations-DesignDays.xls can be found in the macro Datasets folder. The file gives the opportunity to download the ASHRAE design day definitions from the EnergyPlus website [14]. This spreadsheet includes all the data for each of the WMO (World Meteorological Organization) region, as well. Design days are very crucial for the correct energy simulation results and the right HVAC system sizing, hence data from the most recent ASHRAE Handbook of Fundamentals are used, so as to create a set of design day profiles [14]. Moreover, there are EPW files, which are weather files that can be downloaded and be used as input for the EnergyPlus program.

All building surfaces in EnergyPlus are a thin plane without any thickness. Heat conduction and thermal mass calculations is the only reason that the thickness property of the materials should be known. As already mentioned, EnergyPlus geometry is quite simplified and it is shown as a thin layer. This fact creates confusion to the user, who is not sure what the actual proper dimension is. When the differences are small, the most convenient dimensions are the most correct ones, too. In other cases, outside dimensions are suggested for exterior surfaces and centerline dimensions for interior epiphanies [14]. However, when the building under study has very thick masonry walls, centerline dimensions are preferred, so as thermal mass to be provided in a more objective way.

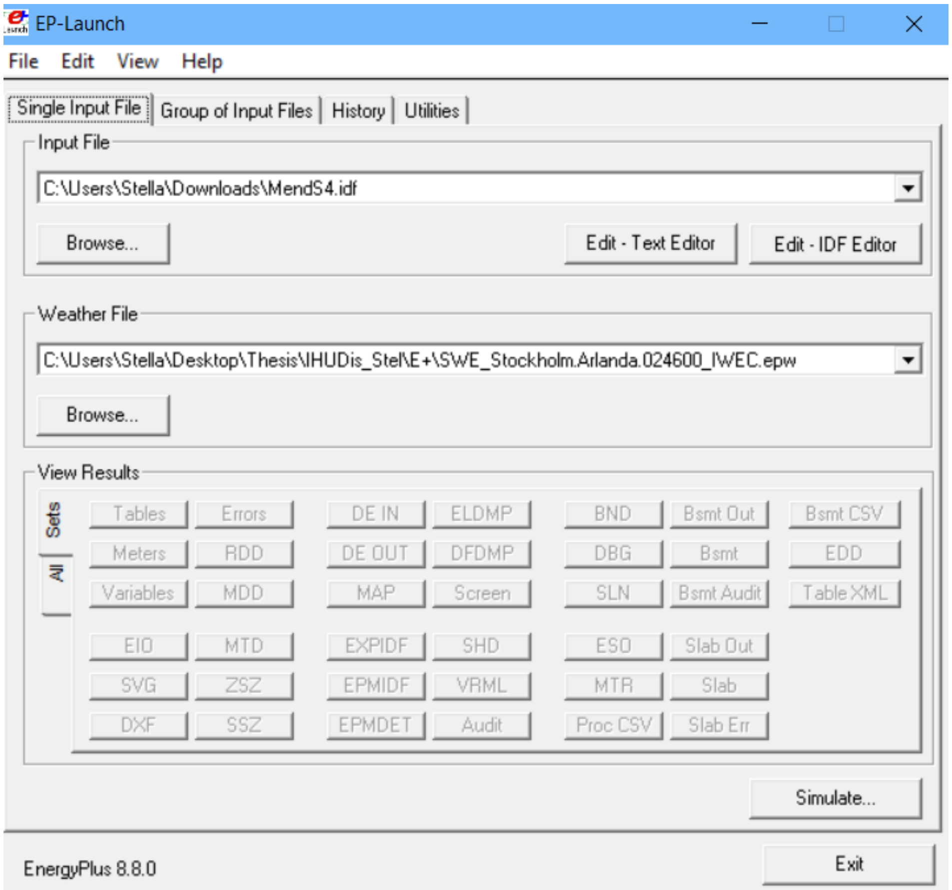
In this coursework, the program of EnergyPlus is cooperating with the programs of Sketch Up and Meteonorm. The building can have more than one thermal zone, windows, doors and separate shading systems. When drawing the geometry in Sketch Up, it would be wise to name every single system, door, zone or window, in order to recognize where the probable error, that may arise, into the IDF editor refers to. After ending the correct geometry of the structure, all the alterations or extra data needed can be added through the IDF file.

Errors that may arise are categorized into crucial (severe, fatal) and simpler (warnings) ones. It is advised that all errors, both warnings and severe, are zero. However, only severe faults must be null in order for the simulation to run, whereas this is not the case for warnings. Some of the most common mistakes are: wrong thermal zone collection, omission of boundary conditions, not completed schedule, unsuccessful surface matching, missed materials or objects, fenestration problems. The standard error message format goes something like this: <module name><routine name> : <object name> = <name field> "condition" <several lines with more information may follow [14].

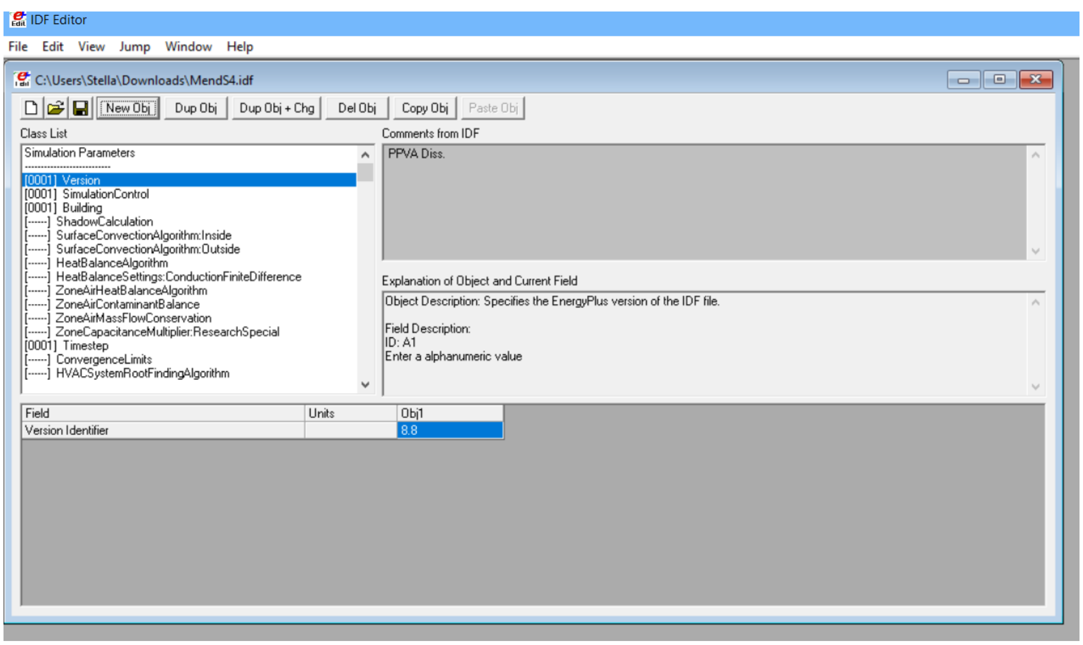
In order to size correctly the HVAC system, some guides are important, like [14]:

- The user can start with a randomly sized system, without controlling any specific equipment
- The system's controls can be coordinated with sizing inputs
- User-specified flow rates will only impact the sizing calculations if entered in the sizing
- Zone thermostat schedules determine the times at which design loads will be calculated

The program gives the possibility to provide output files in table, notepad or excel forms and information provided for monthly basis. Picture 1 and picture 2 show the EP-Launch and the IDF Editor of the 8.8.0 version of EnergyPlus, respectively.



Picture 1: EP-Launch



Picture 2: IDF Editor

3.2 Climatic zones and degree-day method

Building performance examination, as far as energy is concerned, can be quite complicated. In order to simplify the above situation, defining climatic zones within the European territory is not only smart, but also prerequisite to some extent. This classification is based on heating degree day method (HDD) and cooling degree day method (CDD), which leads to more realistic results [15]. The degree-day method belongs to the quasi-steady-state approaches and it is more preferable when long time period calculations are taking place or faster evaluations are needed. Not only across Europe or the world, but also in each different country, separation into climatic zones has been implemented based on the use of degree-day or degree-hour approaches [15].

According to scientists' approach in the site of Investopedia: "A heating degree day (HDD) is a measurement designed to quantify the demand for energy needed to heat a building. It is the number of degrees that a day's average temperature is below 65^{o} Fahrenheit (18^{o} Celsius), which is the temperature below which buildings need to be heated. A cooling degree day (CDD) is a measurement designed to quantify the demand for energy needed to cool a building. It is the number of degrees that a day's average temperature is above 65^{o}Fahrenheit (18^{o}Celsius), which is the temperature above which buildings need to be cooled". The quantity of 18^{o} Celsius is the base temperature both for heating and cooling, according to ASHRAE standards, and it resulted from the combination of theory and empirical observations [15]. Since in Southern Europe climatic conditions are milder, the base temperature, as far as the cooling degree days are concerned, can get the number of 23^{o}. In addition to this, scientists in the site of Wikipedia inform us that base temperatures of 16°C, 18°C and 19°C can be used, while there are some other thresholds like:

- European Union: 15.5^{o}C
- Denmark: 17^{o}C
- Finland: 17^{o}C
- Switzerland: 12^{o}C

It is logical that comparison of HDD between cities is feasible only when the same base temperature is used. It is important to remember that: "One HDD means that temperature conditions outside the building were equivalent to being below a defined threshold comfort temperature inside the building by one degree for one day. Thus heat has to be provided inside the building to maintain thermal comfort." according to scientists in the site of Wikipedia. The general equation of the method contains the mean monthly temperature Tm and the base temperature Tb: HDD (or CDD) $=\sum|Tm-Tb|$.

All in all, one approach for rating European cities into zones is the following one presented in table 1 [16]:

Table 1: Proposed scheme for establishing climatic zones in the European region

Zone	**Description**	**Requirements**
A	CDD≥500, HDD<1500	High cooling needs, low heating needs
B	CDD≥500, 1500≤HDD<3000	High cooling needs, medium heating needs
C	CDD<500, HDD<1500	Low cooling needs, low heating needs
D	CDD<500, 1500≤HDD<3000	Low cooling needs, medium heating needs
E	CDD<500, HDD≥3000	Low cooling needs, high heating needs

It is apparent that heating or cooling needs of an area are proportional to its HDD or CDD, respectively. The number of HDD is representative for the energy demand for space heating, while space cooling is mostly related to electricity consumption. However, there are other factors like income levels, building design and energy systems that affect the above needs. Heating needs are most severe than cooling ones, but these days Mediterranean countries face overheating which makes both needs equally weighty.

In the present thesis, the European cities examined are Larnaca, Athens, Rome, Paris, Berlin, Warsaw and Stockholm. These cities are selected so as to examine the diversity of climatic conditions and take into consideration Southern, Central and Northern Europe. It is important to note that HDD and CDD are taken on monthly basis for the year of 08/2017-08/2018 and, apparently, for the same base temperature, which is 15.5^{o}C. Below, there are nine tables presented, one for each city studied and a final concentrating one.

Table 2: Larnaca, Station: Larnaca Airport, CY (33.62E, 34.87N)

Month Starting	HDD	CDD
08/01/2017	0	404
09/01/2017	0	337
10/01/2017	0	218
11/01/2017	18	86
12/01/2017	58	40
01/01/2018	88	17
02/01/2018	55	28
03/01/2018	34	67
04/01/2018	9	141
05/01/2018	0	270
06/01/2018	0	319
07/01/2018	0	397

Table 3: Athens, Station: Athena Airport, GR (23.73E,37.89N)

Month Starting	HDD	CDD
08/01/2017	0	451
09/01/2017	0	292
10/01/2017	2	125
11/01/2017	39	32
12/01/2017	111	15
01/01/2018	139	2
02/01/2018	91	2
03/01/2018	40	32
04/01/2018	6	119

05/01/2018	0	228
06/01/2018	0	310
07/01/2018	0	391

Table 4: Rome, Station: Roma / Ciampino, IT (12.58E,41.81N)

Month Starting	HDD	CDD
08/01/2017	0	365
09/01/2017	8	132
10/01/2017	32	67
11/01/2017	124	6
12/01/2017	234	0
01/01/2018	162	4
02/01/2018	238	0
03/01/2018	148	3
04/01/2018	39	70
05/01/2018	11	111
06/01/2018	0	211
07/01/2018	0	328

Table 5: Paris, Station: Paris-Orly, FR (2.38E,48.72N)

Month Starting	HDD	CDD
08/01/2017	13	137
09/01/2017	56	37
10/01/2017	84	22
11/01/2017	242	0
12/01/2017	315	0
01/01/2018	247	0
02/01/2018	393	0
03/01/2018	268	0
04/01/2018	100	37

05/01/2018	55	80
06/01/2018	8	128
07/01/2018	0	250

Table 6: Berlin, Station: Erfurt-Bindersleben, DE (10.96E, 50.98N)

Month Starting	HDD	CDD
08/01/2017	14	106
09/01/2017	67	12
10/01/2017	86	10
11/01/2017	262	0
12/01/2017	334	0
01/01/2018	296	0
02/01/2018	418	0
03/01/2018	318	0
04/01/2018	112	33
05/01/2018	63	67
06/01/2018	21	95
07/01/2018	6	176

Table 7: Warsaw, Station: Warszawa-Okecie, PL (20.96E, 52.16N)

Month Starting	HDD	CDD
08/01/2017	16	148
09/01/2017	59	21
10/01/2017	172	6
11/01/2017	315	0
12/01/2017	401	0

01/01/2018	453	0
02/01/2018	516	0
03/01/2018	446	0
04/01/2018	104	53
05/01/2018	20	121
06/01/2018	19	156
07/01/2018	5	200

Table 8: Stockholm, Station: Stockholm / Bromma, SE (17.90E, 59.37N)

Month Starting	**HDD**	**CDD**
08/01/2017	34	56
09/01/2017	88	4
10/01/2017	248	0
11/01/2017	366	0
12/01/2017	448	0
01/01/2018	490	0
02/01/2018	541	0
03/01/2018	547	0
04/01/2018	277	4
05/01/2018	82	75
06/01/2018	40	75
07/01/2018	8	205

Table 9: Classification of European cities according to degree-day method for the period of 08/2017-07/2018

City	HDD	CDD	Category
Larnaca	262	2324	A
Athens	428	1999	A
Rome	996	1297	A

Paris	1781	691	B
Berlin	2469	499	D
Warsaw	2526	486	D
Stockholm	3169	419	E

It is notable that the above cities represent all the weather conditions in Europe. From Larnaca to Stockholm is patent that HDD are increasing, whereas CDD are declining, quite logical since Larnaca is the hottest region and Stockholm the coldest one.

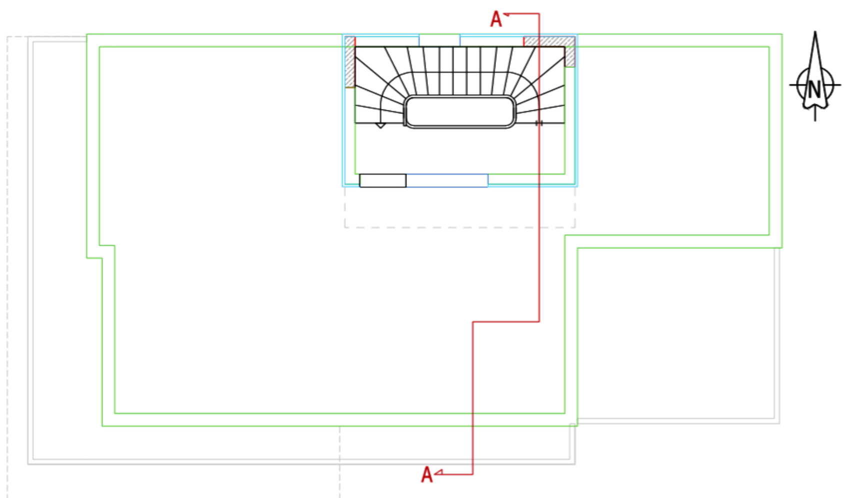
4. Reference Building Study

Since the target has been set and the tools used are clear and understandable, it is time to form the building under study. The design part takes place in the program of Sketch Up and simulations occur under various climatic conditions, according to each region. The most interesting part is the dynamic simulation of the structure in the program of EnergyPlus. The same building is being studied in seven different cities (Larnaca, Athens, Rome, Paris, Berlin, Warsaw, and Stockholm), which are located in the Mediterranean, Central and Northern Europe. In this way, vast discrepancies in energy behavior are apparent, even though the residence is exactly the same.

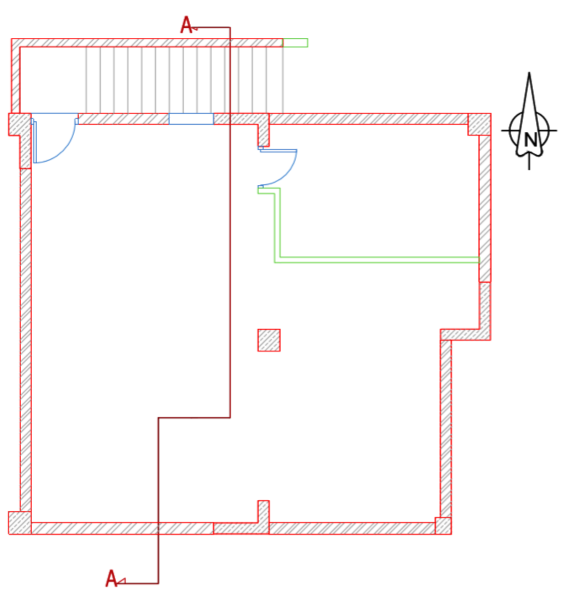
Another important comparison conducted is between the unlike results given from different climatic data files. Freely available climatic files used for simulations in the program of EnergyPlus, will be compared to those created in the special software of Meteonorm. Meteonorm is a unique combination of reliable data sources and sophisticated calculation tools, as it generates precise and proxy typical years for any place on earth, according to scientists in its website. It provides more than 30 different weather parameters, as well. As a result, it is expected that using different climatic data sources, although concerning the same regions, the final results will suffer from alterations.

4.1 Dynamic simulation in the program of EnergyPlus

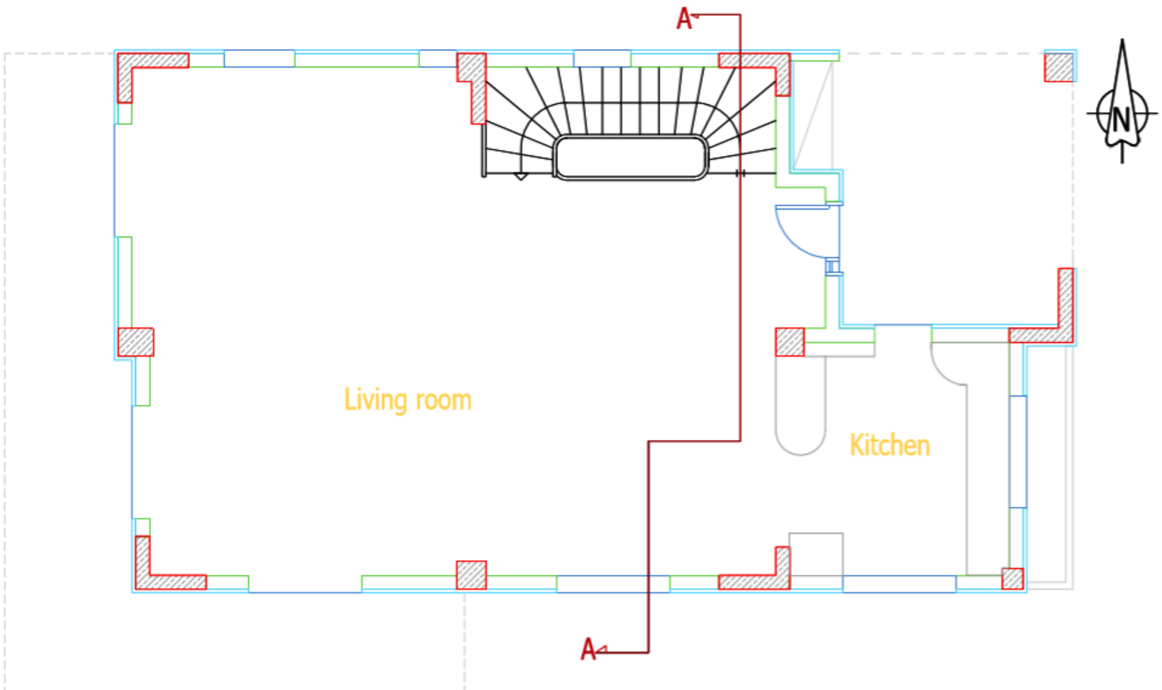
To start with, the reference building is an one-storey residence that is consisted of a basement, ground floor, first floor and terrace. The ground floor contains the living room and the kitchen, whereas the bathroom and the four bedrooms of the house are located on the first floor. Also, the connection between the spaces is feasible only by stairs, since there is no elevator. The area of the ground floor is 87.17 m^2 and its perimeter is 41.2 m, whereas the area of the first floor is 79.33 m^2 and its perimeter is 40.6m. The layouts of the residence are shown in the following pictures, for a better insight of its design:



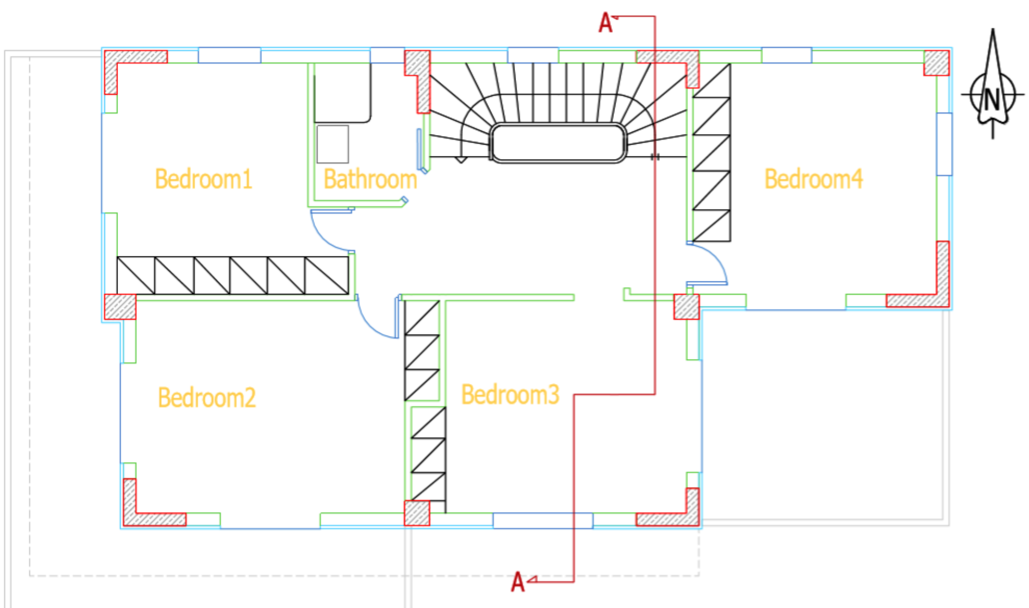
Picture 3: Top view of the terrace



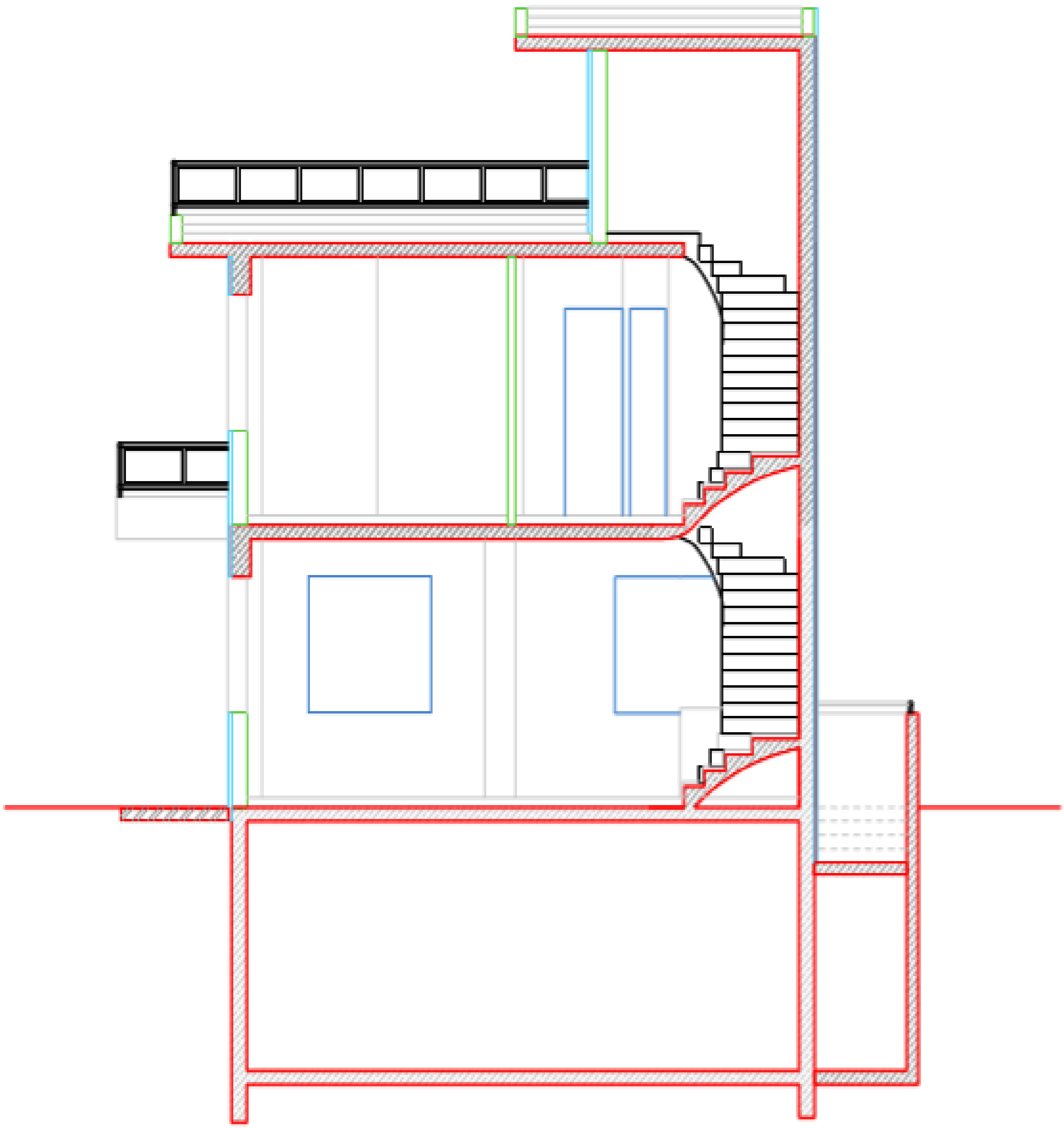
Picture 4: Top view of the basement



Picture 5: Top view of the ground floor



Picture 6: Top view of the first floor



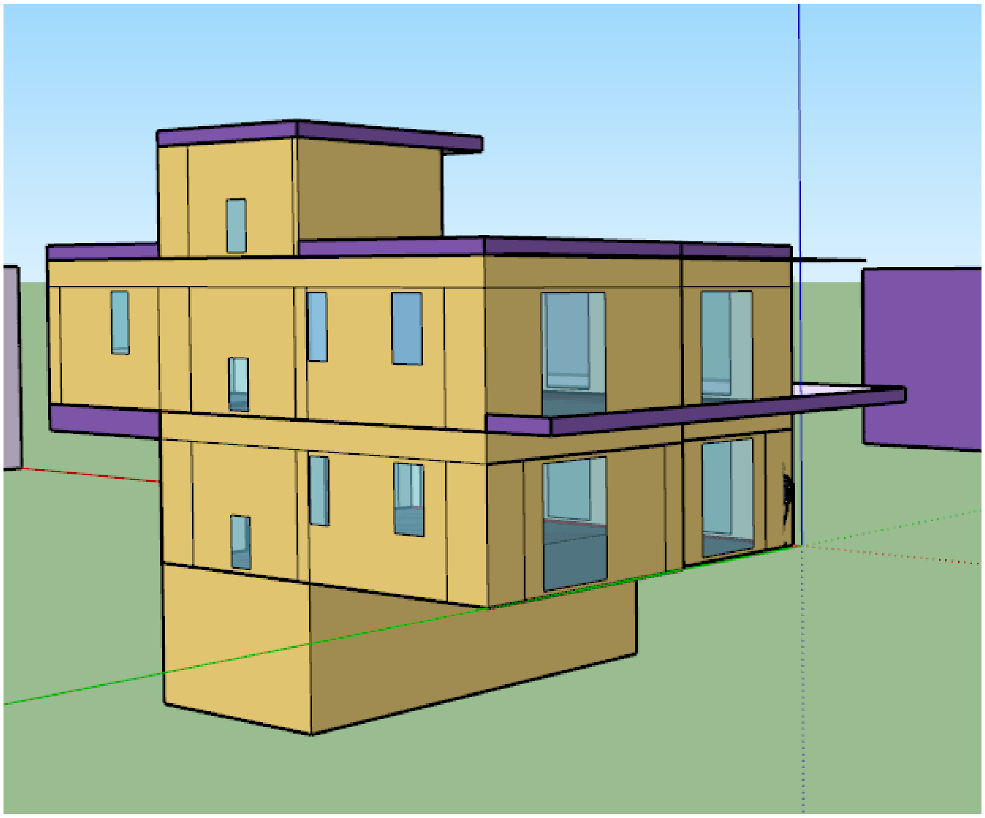
Picture 7: Section A-A

After understanding the design of the building and its spaces, the next step is to redesign the above drawings in the program of Sketch Up, so as to generate the 3-D plan of the residence. Sketching up not only provides a more realistic view of the reference building, but also is the initial key for the simulation in the program of Energy Plus.

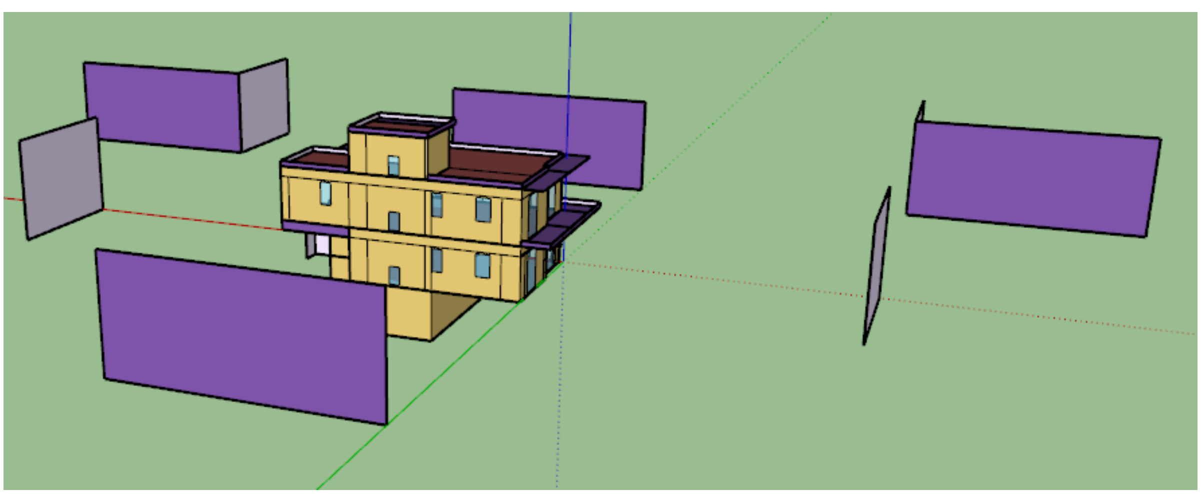
The design part begins with the correct planning of the first thermal zone, which is the ground floor, and continues with three other thermal zones, which are the basement, the first floor and the staircase exit, respectively. Sketching up requires concentration, since only outside dimensions are taking into consideration, while all doors, windows and shading elements must be done with attention at the same time.

The next step, after the perfection of the designing part in Sketch Up, concerns the libraries in the program of EnergyPlus. They must be carefully examined and completed. Changes can be applied directly through the idf editor if necessary. As far as the weather data are concerned, as already mentioned, they are a subject of a parametric study, which means that they are continuously changing. Some extra information given is the following:

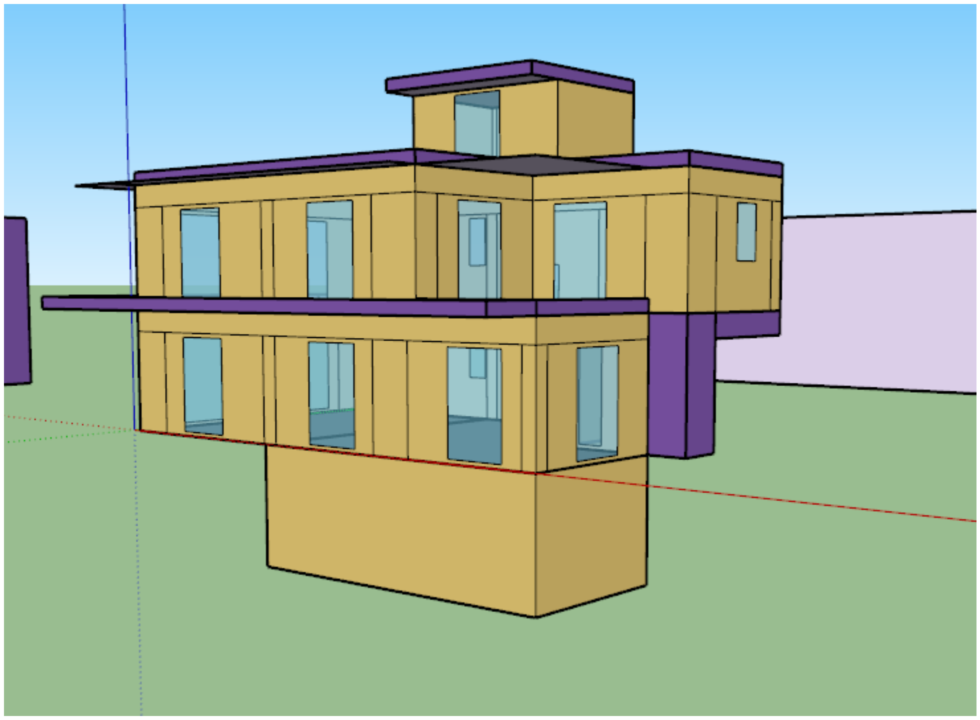
- Occupancy: since there are four bedrooms, the occupants of the residence are five
- Thermal insulation: The material used for insulating the reference building is extruded polystyrene (XPS). Its characteristics are the following:
  -Thermal conductivity λ=0.035 W/ (m*K)
  -Wide applications (roofs, ceilings, walls, cellars) since XPS is a load bearing insulation material
- There is no night insulation
- The boundary condition of the ground floor is adiabatic, so as not to calculate the temperatures of the slab on the ground constantly
- The Southern side of the reference building has many surfaces, so in general the structure has many solar gains
- Final results must be given in kWh/m^2, where the square meters concern the floor area of heated surface and are equal to 188m^2
- The 3-D drawing of the reference building in the program of Sketch Up is presented in the following five pictures



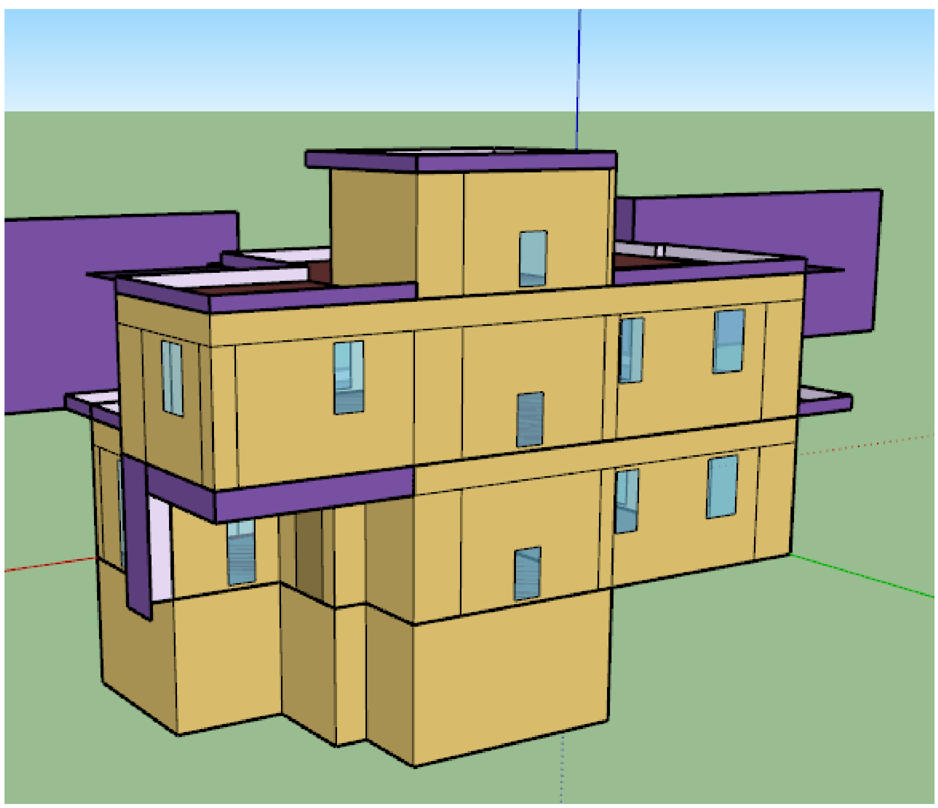
Picture 8: Northwest view of the reference building



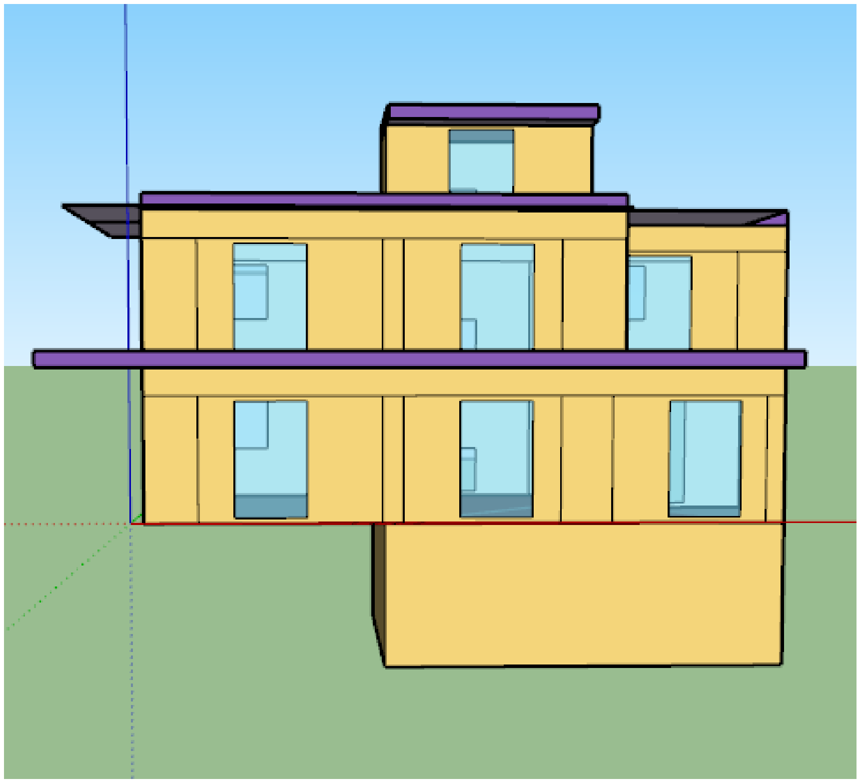
Picture 9: General view of the residence



Picture 10: Southeast view of the reference building



Picture 11: North view of the reference building



Picture 12: South view of the reference building

4.2 Meteonorm software

To start with, Meteonorm is a tool that combines climatic elements with advanced calculation methodologies. This monadic implementation generates typical years for any place on Earth. All the necessary climatic data are obtained from weather stations all over the world. The input of Meteonorm for global radiation is the Global Energy Balance Archive (GEBA), which is a central worldwide database that measures energy fluxes at the surface and it is located at ETH Zurich [16]. The GEBA data fulfills the requirements of the World Meteorological Organization (WMO).

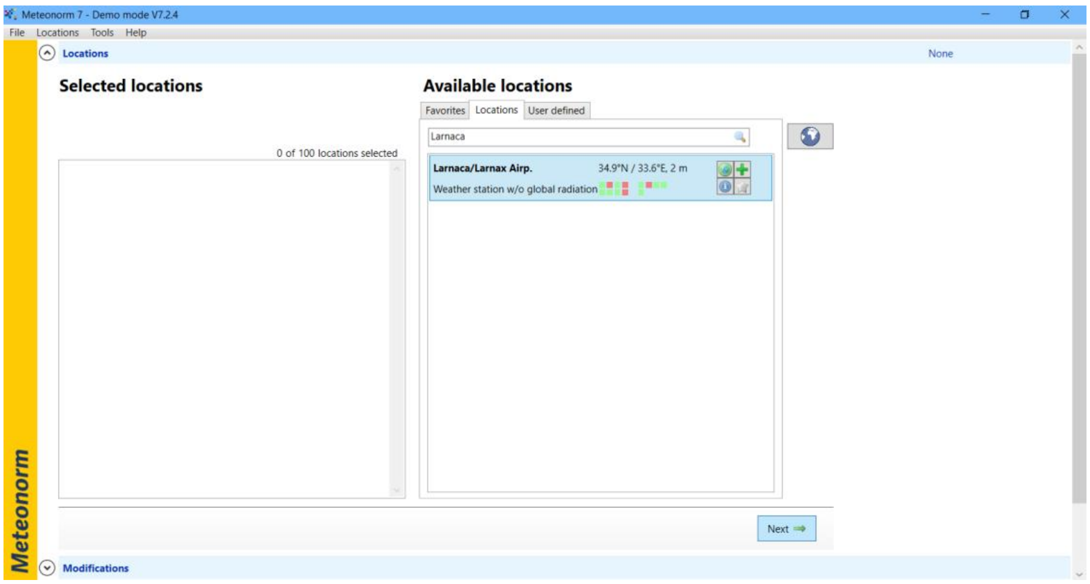
However, in some cases, when the under study region is far away from a met station, satellites are used in order to provide any extra information needed, as far as solar irradiation is concerned. Meteonorm utilizes five geostationary satellites (this means that they are in a stationary distance from the Earth). Unfortunately, this methodology has disadvantages, since there are inaccuracies in areas with snow, there is lack of some meteorological parameters and uncertainties in aerosol values. Nevertheless, Meteonorm combines weather and satellite data in order to manage the lowest precariousness.

In addition to this, reliability is undeniable, since the software offers 30 and more parameters, such as: Global, direct and diffuse irradiation on horizontal and inclined surface, temperature, relative humidity, wind speed, cloud cover, Illuminance, UVA/UV radiation, snow depth, atmospheric pressure, precipitation, days with precipitation, sunshine duration, dew point temperature, wet bulb temperature, surface temperature. Using all the relevant weather data combined with a stochastic model, Meteonorm provides hourly values of all parameters. There is a large difference between generating hourly and minute values, since the second ones are more detailed and accurate. Although the derivation of minute values requires harsher labor and expenses, Meteonorm implements two new minute models, as well.

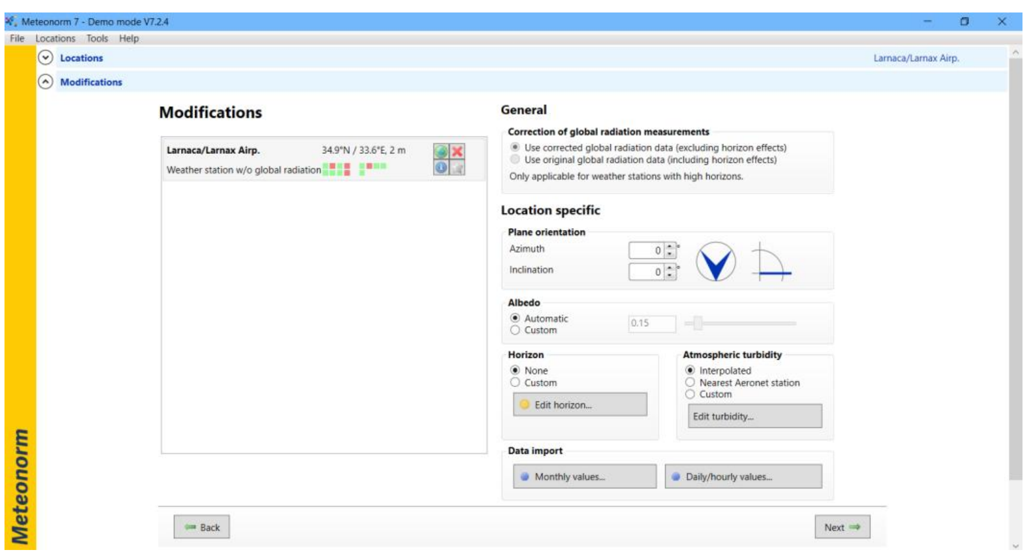
Some basic steps using the software of Meteonorm are presented below:

- First of all, at the location tab, the user can search for the location under study or use the map tool to find it. Then, click on select location for calculation (+). Click on the Next button
- The next step is to specify the orientation and the tilt angle required. Click on the Next button
- After that, the user can modify some data settings. Either keep the default settings or for future periods, choose: period radiation: future, period temperature: future and collect the scenario future year. Click on the Next button
- In the next section the user can specify the output format. Usually, keep the standard format. Click on the Next button
- In the final section the results of the calculations are presented. There are several tabs ready for exploration, like monthly diffuse and global irradiation on horizontal surface or temperature profile of the location. The most important tab is the table of monthly and annual values for several parameters including global horizontal irradiation and global tilted irradiation at the specified inclination

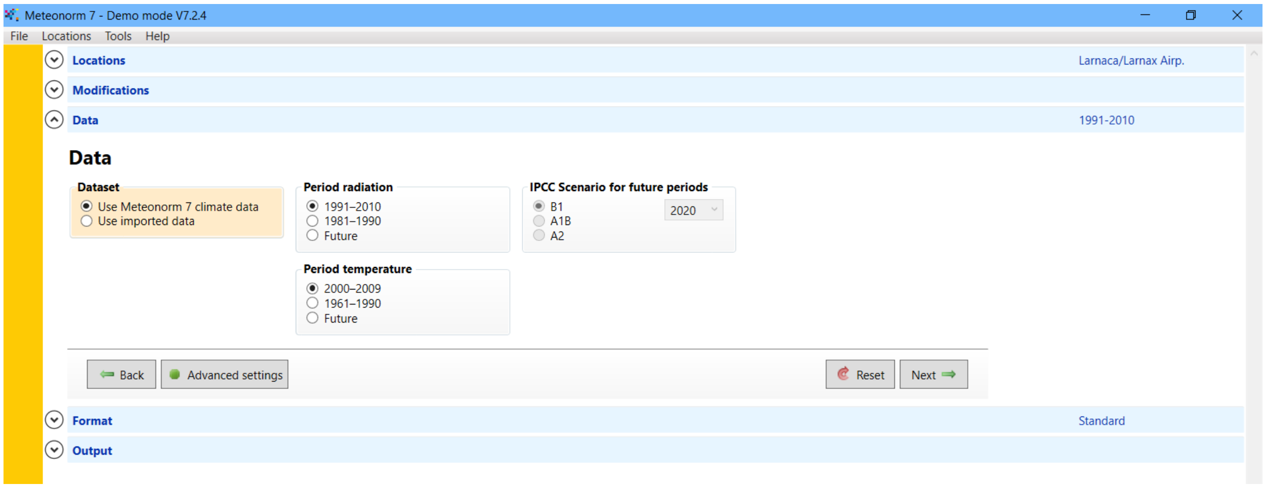
- Now, the user can copy the table in excel spreadsheet and paste it
- Monthly irradiation on inclined surface can be converted into daily irradiation by dividing it by the number of days in each month
- The yearly average daily irradiation can be also found
- Finally, save the results to a text file by clicking "save all results to disk", then choosing the output format



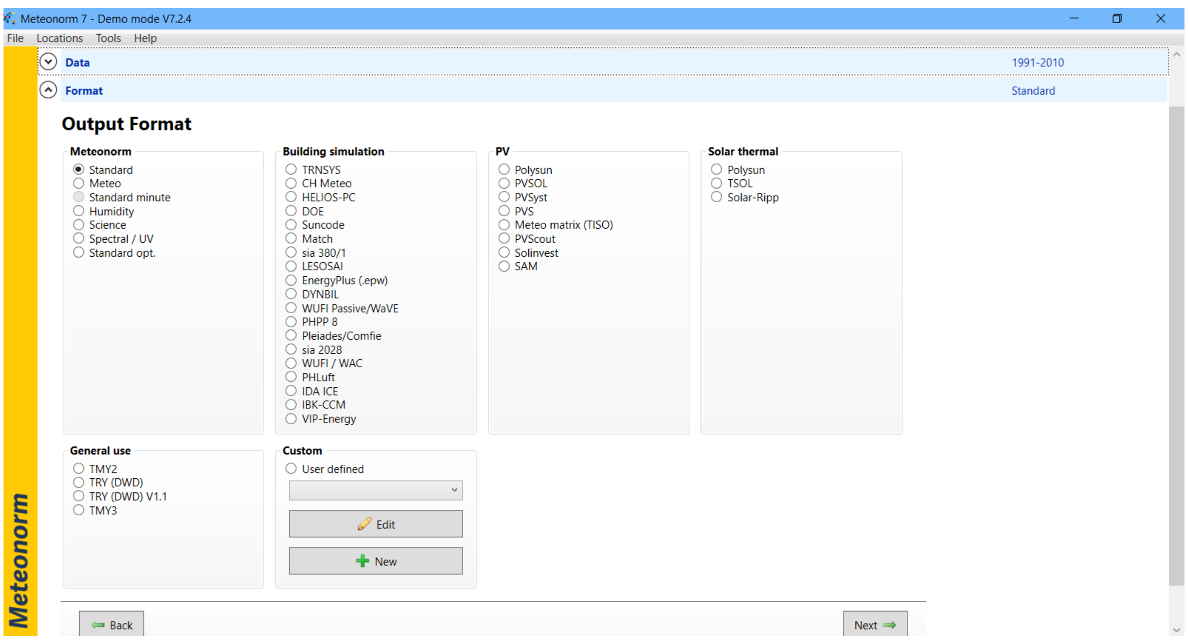
Picture 13: Locations tab in Meteonorm software



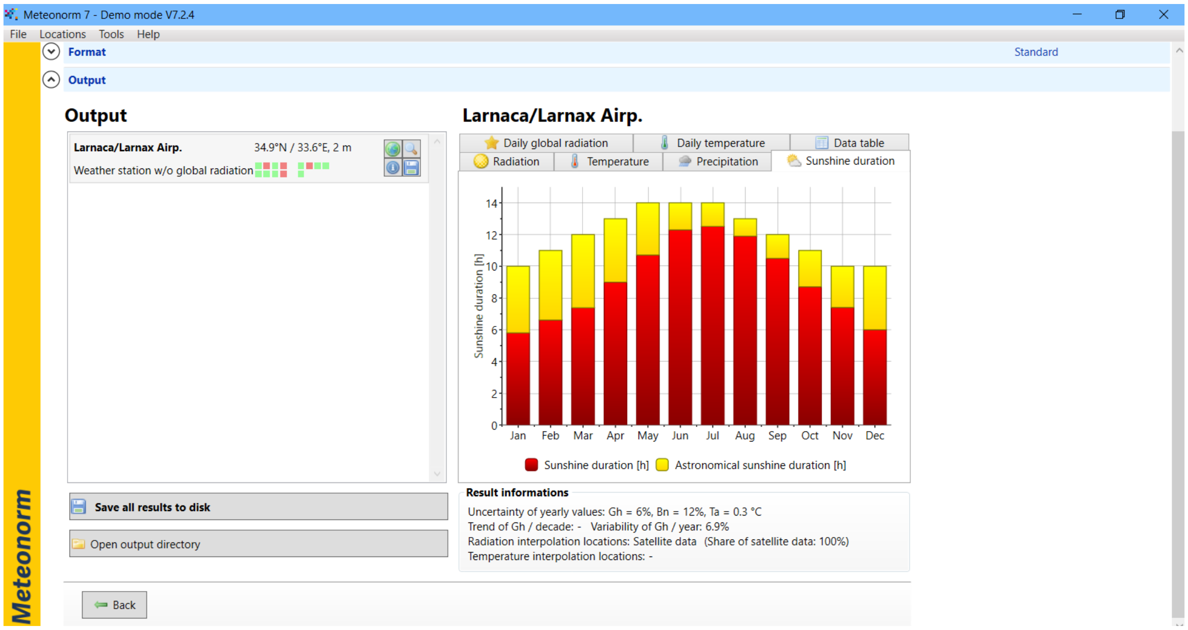
Picture 14: Modifications tab in Meteonorm software



Picture 15: Data settings in Meteonorm software



Picture 16: Output Format in Meteonorm software



Picture 17: Output tab in Meteonorm software

As far as the *future scenarios* are concerned, there are three possible cases, according to the intergovernmental panel on climate change, which are presented in the table below. Nowadays, more accurate climate change estimation is feasible due to technological advances, so uncertainty ranges are provided for prolonged warming for different emission scenarios. B1, A2 and A1B cases are studied, with the following information [17]:

Table 10: Projected global average surface warming and sea level rise at the end of the 21st century

	Temperature Change (^{o}C at 2090-2099 relative to 1980-1999)		Sea level rise (m at 2090-2099 relative to 1980-1999)
Case	Best estimate	Likely range	Model based range excluding future rapid dynamical changes in ice flow
B1	1.8	1.1-2.9	0.18-0.38
A2	3.4	2.0-5.4	0.23-0.51
A1B	2.8	1.7-4.4	0.21-0.48

To be more specific, these scenarios encompass economic, technological and demographic characteristics of the future, which are strongly related to greenhouse gas and sulphur emissions. They are based on the same storyline, which is the Special Report on Emissions Scenarios, however they describe deviant futures (SRES).

The main traits of A1 scenario are affluent people, evolvement of the economy and productivity, which means blossom of new technologies, as well [18]. The global population remains the same until the mid century and declines thereafter. The A1 scenario family is separated into three sub-groups contingent on different energy systems based on technological advances. These categories are: A1F1 (fossil intensive), A1T (non-fossil energy sources) and A1B (balance across all sources). In this coursework, the category examined is the last one, A1B, which examines a world that is not dependent only on one sole energy source [18].

The A2 storyline analyzes a world full of diversities. Society is self-dependent with strong preservation of local characteristics. Technological advances are not so developed, as in the other scenarios, and economic growth is restricted in regional boundaries [19].

Finally, the B1 scenario family describes a society that enters new resource- efficient technologies and not a so material dependent world. The global population remains the same until the mid century, when is its peak, and declines thereafter, as in the A1 scenario. The target is balance in the sectors of economy, society and environment [20].

5. Analysis

This chapter is the continuation of chapter 4, since all the results that come from the above simulations are analyzed here. Energy consumption and performance results of the reference building are presented, both for multi-year climatic data and freely available data. The presentation, comparison and analysis are done with the help of diagrams and tables.

It is important to notice that all results are given in kWh or kWh/m^2, which is the unit for energy consumption. In this thesis, energy needs are related to energy consumption and not to energy demand, since consumption represents the amount of energy spent over a certain period. In other words, kWh is a measure of energy, whereas kW, which stands for energy demand, is a measure of power. Power is the rate at which energy is generated. Only if energy is transmitted or used at a constant rate over a period of time, then the total energy in kilowatt hours is equal to the power in kilowatts multiplied by the time in hours.

5.1 Simulation results of the various climatic conditions in the program of EnergyPlus with respect to freely available data

Firstly, simulations with freely available data found in the website of EnergyPlus will take place. It is expected that the Northern the location gets, the more the heating needs are and the less the cooling needs are. Concentrating results in kWh for every city are displayed from table 11 to table 17, while table 18 denotes concentrating results in kWh/m^2 for all cities.

Table 11: Monthly report of the sensible energy spend in kWh, Larnaca

	Sensible heating energy	**Sensible cooling energy**
January	135	0

February	145	0
March	37	0
April	2	49
May	0	612
June	0	1545
July	0	2302
August	0	2467
September	0	1909
October	0	613
November	0	0
December	11	0
Annual sum or Average	**330**	**9497**

Table 12: Monthly report of the sensible energy spend in kWh, Athens

	Sensible heating energy	**Sensible cooling energy**
January	645	0
February	786	0
March	446	0
April	23	0
May	0	289
June	0	1517
July	0	2444
August	0	2448
September	0	1587
October	0	335
November	10	0
December	650	0
Annual sum or Average	**2560**	**8620**

Table 13: Monthly report of the sensible energy spend in kWh, Rome

	Sensible heating energy	**Sensible cooling energy**
January	1450	0
February	833	0
March	489	0
April	69	0
May	0	58
June	0	678
July	0	1462
August	0	1574
September	0	881
October	6	223
November	172	0
December	1105	0
Annual sum or Average	**4124**	**4876**

Table 14: Monthly report of the sensible energy spend in kWh, Paris

	Sensible heating energy	**Sensible cooling energy**
January	3412	0
February	2827	0
March	2127	0
April	977	0
May	0	0
June	0	14
July	0	310
August	0	516
September	0	17
October	486	0
November	2232	0

December	3344	0
Annual sum or Average	**15405**	**857**

Table 15: Monthly report of the sensible energy spend in kWh, Berlin

	Sensible heating energy	**Sensible cooling energy**
January	4309	0
February	4049	0
March	2700	0
April	1191	0
May	0	0
June	0	229
July	0	216
August	0	275
September	0	1
October	983	0
November	3085	0
December	4250	0
Annual sum or Average	**20567**	**721**

Table 16: Monthly report of the sensible energy spend in kWh, Warsaw

	Sensible heating energy	**Sensible cooling energy**
January	5384	0
February	4631	0
March	3154	0
April	1134	0
May	0	0
June	0	0
July	0	118

August	0	122
September	0	0
October	1550	0
November	3370	0
December	5004	0
Annual sum or Average	**24227**	**241**

Table 17: Monthly report of the sensible energy spend in kWh, Stockholm

	Sensible heating energy	**Sensible cooling energy**
January	6076	0
February	4472	0
March	4124	0
April	2164	0
May	0	0
June	0	15
July	0	67
August	0	57
September	0	0
October	2188	0
November	4028	0
December	5738	0
Annual sum or Average	**28791**	**139**

Table 18: Concentrating results in kWh/m^2, freely-available data

	Heating Energy (kWh)	**Heating Energy (kWh/m^2)[/188]**	**Cooling Energy (kWh)**	**Cooling Energy (kWh/m^2)[/188]**
Larnaca	330	2	9497	51
Athens	2561	14	8620	46

Rome	4123	22	4875	26
Paris	15405	82	856	5
Berlin	20567	109	721	4
Warsaw	24227	129	241	1
Stockholm	28791	153	139	1

The table depicts a quite expected and logical result, which is the increasing pattern of heating energy needs and the decreasing pattern of cooling energy needs, as the city examined gets Northern. Larnaca has the lowest heating energy needs, but the highest cooling ones, whereas the exact opposite happens to Stockholm. Ultimately, the above table gives a general idea about the energy needs of each city. These patterns are more pronounced if the results are given in a diagram shape. So, diagram 1 below depicts the energy needs of each city, based on freely- available climatic data.

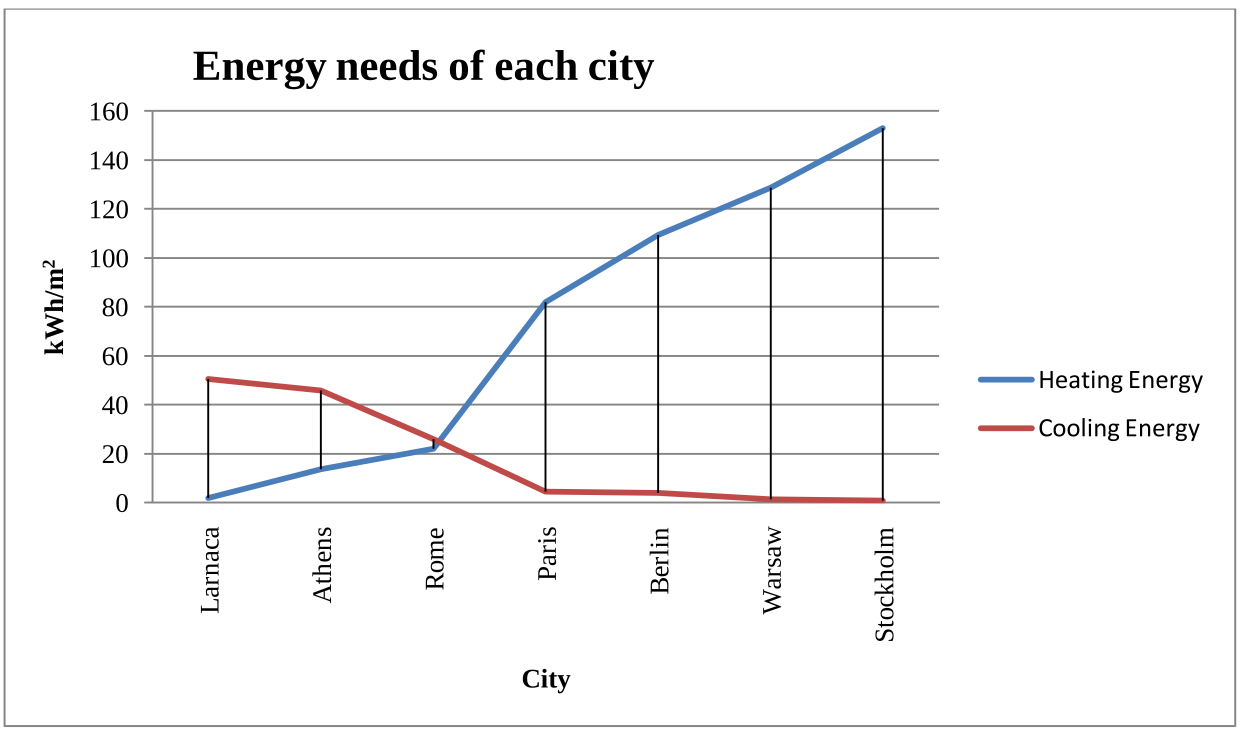


Diagram 1: Energy needs of each city, freely- available climatic data

5.2 Simulation results of the various climatic conditions in the program of EnergyPlus with respect to multi-year climatic data

The program of Meteonorm provides the possibility to calculate energy results concerning both past years and future scenarios. In this section simulation is taking place for the past year of 2010, which is widely used for simulations in Greece. In addition to this, simulations for the years of 2040, 2050, 2060 concerning A1B, A2 and B1 scenarios are carried out.

5.2.1 Results for the year of 2010

Results for each city separately and for the year of 2010, based on multi-year climatic data, are presented in this sub-chapter. In addition to this, table 27 denotes the comparison between freely available and multi- year climatic data simulation results in kWh/m^2.

Table 19: Monthly report of the sensible energy spend in kWh, Larnaca

	Sensible heating energy	**Sensible cooling energy**
January	133	0
February	44	0
March	5	0
April	0	12
May	0	864
June	0	2042
July	0	2715
August	0	2724
September	0	2049
October	0	843
November	0	0

December	5	0
Annual sum or Average	**187**	**11247**

Table 20: Monthly report of the sensible energy spend in kWh, Athens

	Sensible heating energy	**Sensible cooling energy**
January	269	0
February	572	0
March	245	0
April	2	0
May	0	396
June	0	1673
July	0	2678
August	0	2731
September	0	1707
October	0	588
November	0	0
December	124	0
Annual sum or Average	**1212**	**9772**

Table 21: Monthly report of the sensible energy spend in kWh, Rome

	Sensible heating energy	**Sensible cooling energy**
January	1150	0
February	971	0
March	338	0
April	31	0
May	0	254
June	0	1108
July	0	1770
August	0	1789

September	0	814
October	0	109
November	65	0
December	1115	0
Annual sum or Average	**3670**	**5843**

Table 22: Monthly report of the sensible energy spend in kWh, Paris

	Sensible heating energy	**Sensible cooling energy**
January	2820	0
February	2209	0
March	1179	0
April	235	0
May	0	48
June	0	359
July	0	747
August	0	703
September	0	24
October	154	6
November	1337	0
December	2619	0
Annual sum or Average	**10553**	**1888**

Table 23: Monthly report of the sensible energy spend in kWh, Berlin

	Sensible heating energy	**Sensible cooling energy**
January	3840	0
February	2974	0
March	2094	0
April	318	0

May	0	25
June	0	364
July	0	778
August	0	630
September	0	153
October	319	0
November	2214	0
December	3818	0
Annual sum or Average	**15576**	**1950**

Table 24: Monthly report of the sensible energy spend in kWh, Warsaw

	Sensible heating energy	**Sensible cooling energy**
January	4886	0
February	3739	0
March	2671	0
April	783	0
May	0	10
June	0	203
July	0	874
August	0	580
September	0	58
October	649	0
November	2815	0
December	4295	0
Annual sum or Average	**19838**	**1725**

Table 25: Monthly report of the sensible energy spend in kWh, Stockholm

	Sensible heating energy	**Sensible cooling energy**
January	5223	0
February	4481	0
March	3348	0
April	1294	0
May	0	0
June	0	23
July	0	500
August	0	202
September	0	12
October	1541	0
November	3584	0
December	4787	0
Annual sum or Average	**24258**	**737**

Table 26: Concentrating results in kWh/m^2, multi-year climatic data (2010)

	Heating Energy (kWh)	**Heating Energy (kWh/m^2)[/188]**	**Cooling Energy (kWh)**	**Cooling Energy (kWh/m^2)[/188]**
Larnaca	187	1	11247	60
Athens	1212	6	9772	52
Rome	3670	20	5843	31
Paris	10553	56	1888	10
Berlin	15576	83	1950	10
Warsaw	19838	106	1725	9
Stockholm	24258	129	737	4

Table 26 depicts the same fact as table 18, which is the increasing pattern of heating needs and the decreasing pattern of cooling energy needs, as the city examined gets Northern. The results, of course, are not the same, since the climatic data used differ.

As a result, it is of great importance to present on a common table the different results that come from various climatic data. Table 27 below demonstrates this comparison between freely available climatic data simulation results and multi-year climatic data simulation results concerning the year of 2010.

Table 27: Comparison between freely available and multi- year climatic data simulation results in kWh/m^2

	Heating Energy-Freely available data	**Heating Energy-Meteonorm data**	**Cooling Energy-Freely available data**	**Cooling Energy –Meteonorm data**
Larnaca	2	1	51	60
Athens	14	6	46	52
Rome	22	20	26	31
Paris	82	56	5	1
Berlin	109	83	4	10
Warsaw	129	106	1	9
Stockholm	153	129	1	4

The fact that climatic data freely given from the website of EnergyPlus and climatic data generated from the software of Meteonorm provide different results, although the cities and the year is the same, indicates the sensitivity of the simulations performed. In a simple and ideal world, climatic data should be the same, since they express the typical climatic conditions of an area. However, this is not the case in reality. It is obvious that climatic data derived from different sources give unlike results, so there is insecurity as far as climatic data are concerned. Diagram 2 below gives a more illustrative comparison of the above results.

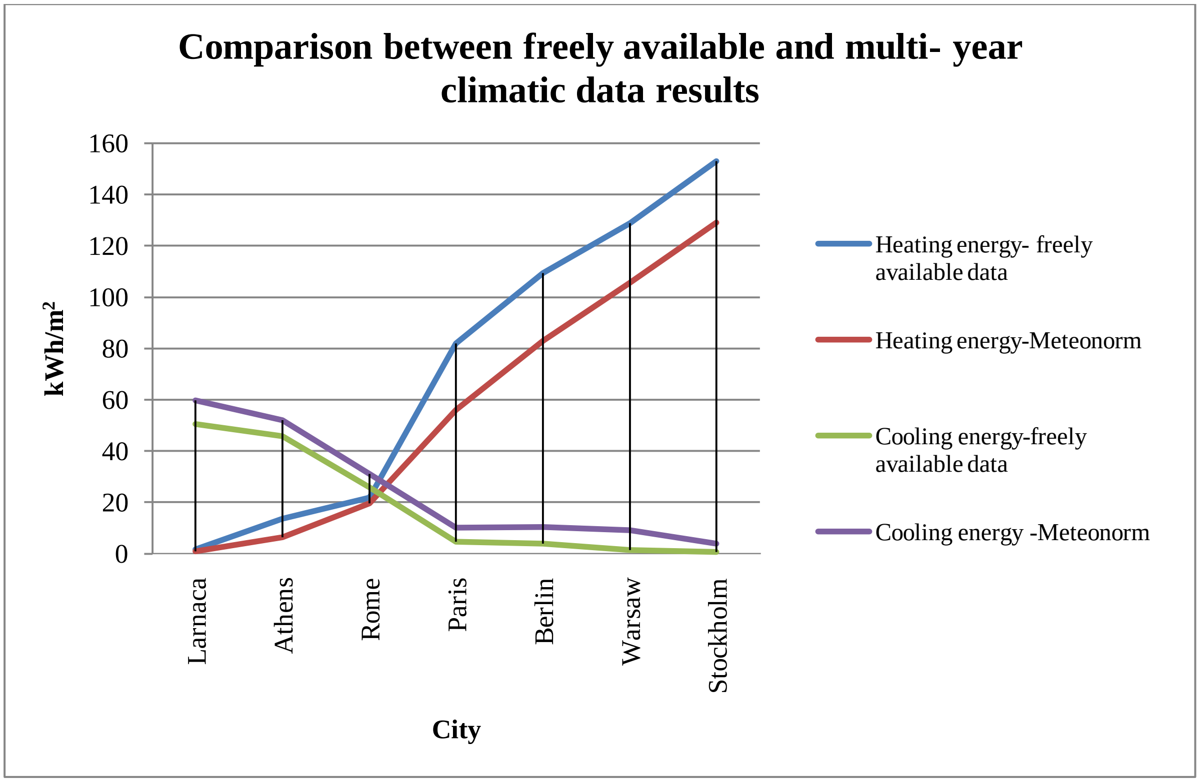


Diagram 2: Comparison between freely available and multi- year climatic data simulation results in kWh/m^2

5.2.2 Simulation results for the year of 2040

Future year of 2040 is going to be examined in this section. It is important to note that future predictions concerning the climate consist of 3 possible scenarios, which are examined below and are already analyzed in chapter 4. These scenarios are A1B, A2 and B1 and are related to uncertainty ranges.

Table 28: Monthly needs in Larnaca in kWh, year 2040

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	21	0	12	0	28	0
February	24	0	43	0	33	0
March	4	0	2	0	6	0

April	0	37	0	23	0	22
May	0	928	0	916	0	839
June	0	2016	0	1966	0	1937
July	0	2751	0	2701	0	2657
August	0	2715	0	2671	0	2607
September	0	2206	0	2168	0	2117
October	0	915	0	891	0	888
November	0	0	0	0	0	0
December	0	0	1	0	1	0

Table 29: Annual energy needs in Larnaca, year 2040

	A1B	**A2**	**B1**
Heating energy(kWh)	49	58	68
Cooling energy (kWh)	11566	11336	11067
Heating energy (kWh/m^2)	0	0	0
Cooling energy (kWh/m^2)	62	60	59

Table 30: Monthly needs in Athens in kWh, year 2040

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	177	0	160	0	205	0
February	314	0	316	0	357	0
March	52	0	89	0	64	0

April	1	0	0	2	2.296	0
May	0	718	0	752	0	631
June	0	2059	0	1977	0	1981
July	0	3103	0	3055	0	2952
August	0	3138	0	3089	0	3000
September	0	2255	0	2210	0	2210
October	0	653	0	644	0	641
November	0	0	0	0	0	0
December	26	0	27	0	67	0

Table 31: Annual energy needs in Athens, year 2040

	A1B	**A2**	**B1**
Heating energy(kWh)	570	592	695
Cooling energy (kWh)	11925	11728	11416
Heating energy (kWh/m^2)	3	3	4
Cooling energy (kWh/m^2)	63	62	61

Table 32: Monthly needs in Rome in kWh, year 2040

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	731	0	686	0	721	0
February	656	0	543	0	724	0

March	159	0	168	0	177	0
April	1	0	7	0	3	0
May	0	316	0	314	0	274
June	0	1344	0	1375	0	1314
July	0	2323	0	2274	0	2251
August	0	2306	0	2314	0	2184
September	0	1464	0	1428	0	1316
October	0	489	0	306	0	422
November	11	0	22	0	29	0
December	621	0	620	0	709	0

Table 33: Annual energy needs in Rome, year 2040

	A1B	**A2**	**B1**
Heating energy(kWh)	2179.	2047	2362
Cooling energy (kWh)	8242	8011	7762
Heating energy (kWh/m^2)	12	11	13
Cooling energy (kWh/m^2)	44	43	41

Table 34: Monthly needs in Paris in kWh, year 2040

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	2534	0	2553	0	2583	0

February	2113	0	2092	0	2185	0
March	1187	0	1339	0	1320	0
April	381	0	403	0	330	0
May	0	1.219	0	0	0	0
June	0	252.385	0	219	0	198
July	0	868.837	0	846	0	788
August	0	982.683	0	913	0	867
September	0	272.674	0	267	0	232
October	39	0	122	0	117	0
November	1306	0	1342	0	1418	0
December	2495	0	2503	0	2555	0

Table 35: Annual energy needs in Paris, year 2040

	A1B	**A2**	**B1**
Heating energy(kWh)	10054	10355	10508
Cooling energy (kWh)	2378	2245	2086
Heating energy (kWh/m^2)	53	55	56
Cooling energy (kWh/m^2)	13	12	11

Table 36: Monthly needs in Berlin in kWh, year 2040

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	399	0	3708	0	4004	0

February	3053	0	3057	0	3134	0
March	1818	0	1946	0	1885	0
April	559	0	455	0	604	0
May	0	5	0	15	0	3
June	0	315	0	453	0	341
July	0	867	0	724	0	850
August	0	787	0	683	0	729
September	0	113	0	286	0	85
October	245	0	245	0	297	0
November	1989	0	2058	0	2070	0
December	3410	0	3566	0	3473	0

Table 37: Annual energy needs in Berlin, year 2040

	A1B	**A2**	**B1**
Heating energy(kWh)	15066	15034	15467
Cooling energy (kWh)	2087	2161	2008
Heating energy (kWh/m^2)	80	80	82
Cooling energy (kWh/m^2)	11	11	11

Table 38: Monthly needs in Warsaw in kWh, year 2040

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	4865	0	4936	0	4832	0
February	3690	0	3637	0	3485	0

March	2486	0	2457	0	2647	0
April	833	0	921	0	725	0
May	0	26.05	0	75	0	0
June	0	273.16	0	220	0	276
July	0	789.482	0	665	0	773
August	0	724.078	0	640	0	507
September	0	77.041	0	70	0	36
October	610	0	637	0	601	0
November	2332	0	2451	0	2607	0
December	3980	0	4025	0	4056	0

Table 39: Annual energy needs in Warsaw, year 2040

	A1B	**A2**	**B1**
Heating energy(kWh)	18795	19064	18953
Cooling energy (kWh)	1890	1671	1592
Heating energy (kWh/m^2)	100	101	101
Cooling energy (kWh/m^2)	10	9	8

Table 40: Monthly needs in Stockholm in kWh, year 2040

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	5156	0	5176	0	5215	0
February	4418	0	4239	0	4326	0
March	3264	0	3252	0	3360	0
April	1199	0	1111	0	1209	0

May	0	0	0	0	0	0
June	0	115	0	143	0	89
July	0	686	0	596	0	605
August	0	167	0	143	0	145
September	0	6	0	23	0	8
October	1000	0	1336	0	1348	0
November	3365	0	3326	0	3445	0
December	4625	0	4614	0	4573	0

Table 41: Annual energy needs in Stockholm, year 2040

	A1B	**A2**	**B1**
Heating energy(kWh)	23027	23054	23476
Cooling energy (kWh)	974	905	848
Heating energy (kWh/m^2)	122	123	125
Cooling energy (kWh/m^2)	5	5	5

5.2.3 Simulation results for the year of 2050

Future year of 2050 is going to be examined in this section. It is important to note that future predictions concerning the climate consist of 3 possible scenarios, which are examined below and are already analyzed in chapter 4. These scenarios are A1B, A2 and B1 and are related to uncertainty ranges.

Table 42: Monthly needs in Larnaca in kWh, year 2050

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	14	0	7	0	22	0
February	6	0	7	0	10	0
March	1	0	0	0	2	0
April	0	67	0	35	0	43
May	0	1038	0	964	0	879
June	0	2100	0	2066	0	1966
July	0	2839	0	2772	0	2681
August	0	2817	0	2748	0	2655
September	0	2305	0	2237	0	2172
October	0	963	0	869	0	841
November	0	0	0	0	0	0
December	0	0	2	0	0	0

Table 43: Annual energy needs in Larnaca, year 2050

	A1B	**A2**	**B1**
Heating energy(kWh)	20	17	34
Cooling energy (kWh)	12129	11691	11237
Heating energy (kWh/m^2)	0	0	0
Cooling energy (kWh/m^2)	65	62	60

Table 44: Monthly needs in Athens in kWh, year 2050

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	152	0	134	0	187	0
February	245	0	256	0	310	0
March	0	0	33	0	91	0
April	0	2	0	0	0	0
May	0	865	0	826	0	706
June	0	2227	0	2017	0	2003
July	0	3248	0	3221	0	3025
August	0	3270	0	3173	0	3051
September	0	2410	0	2334	0	2264
October	0	763	0	739	0	716
November	0	0	0	0	0	0
December	12	0	8	0	27	0

Table 45: Annual energy needs in Athens, year 2050

	A1B	**A2**	**B1**
Heating energy(kWh)	438	430	616
Cooling energy (kWh)	12784	12400	11764
Heating energy (kWh/m^2)	2	2	3
Cooling energy (kWh/m^2)	68	66	63

Table 46: Monthly needs in Rome in kWh, year 2050

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	726	0	676	0	696	0
February	431	0	557	0	634	0
March	91	0	163	0	76	0
April	1	0	0	0	1	0
May	0	365	0	339	0	332
June	0	1470	0	1428	0	1368
July	0	2408	0	2366	0	2294
August	0	2425	0	2419	0	2290
September	0	1606	0	1543	0	1428
October	0	400	0	305	0	271
November	17	0	16	0	8	0
December	555	0	531	0	612	0

Table 47: Annual energy needs in Rome, year 2050

	A1B	**A2**	**B1**
Heating energy(kWh)	1821	1943	2026
Cooling energy (kWh)	8674	8400	7983
Heating energy (kWh/m^2)	10	10	11
Cooling energy (kWh/m^2)	46	45	42

Table 48: Monthly needs in Paris in kWh, year 2050

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	2559	0	2592	0	2517	0
February	1888	0	1908	0	2010	0
March	1105	0	1216	0	1214	0
April	381	0	386	0	412	0
May	0	3	0	0	0	3
June	0	189	0	158	0	248
July	0	1038	0	1002	0	869
August	0	1145	0	1150	0	921
September	0	342	0	306	0	272
October	53	0	66	1	165	0
November	1303	0	1341	0	1416	0
December	2183	0	2321	0	2330	0

Table 49: Annual energy needs in Paris, year 2050

	A1B	**A2**	**B1**
Heating energy(kWh)	9472	9830	10064
Cooling energy (kWh)	2717	2617	2314
Heating energy (kWh/m^2)	50	52	54
Cooling energy (kWh/m^2)	14	14	12

Table 50: Monthly needs in Berlin in kWh, year 2050

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	3622	0	3606	0	3621	0
February	2915	0	2862	0	2929	0
March	1796	0	1926	0	1894	0
April	377	0	316	0	436	0
May	0	4	0	17	0	6
June	0	419	0	447	0	386
July	0	894	0	819	0	859
August	0	840	0	784	0	722
September	0	101	0	157	0	131
October	262	1	325	0	172	0
November	2082	0	2101	0	2114	0
December	3325	0	3361	0	3424	0

Table 51: Annual energy needs in Berlin, year 2050

	A1B	**A2**	**B1**
Heating energy(kWh)	14379	14497	14589
Cooling energy (kWh)	2260	2225	2104
Heating energy (kWh/m^2)	76	77	78
Cooling energy (kWh/m^2)	12	12	11

Table 52: Monthly needs in Warsaw in kWh, year 2050

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	4777	0	4727	0	4845	0
February	3462	0	3267	0	3474	0
March	2401	0	2586	0	2545	0
April	605	0	681	0	746	0
May	0	55	0	0.754	0	33
June	0	273	0	297.752	0	258
July	0	879	0	735.54	0	780
August	0	827	0	606.35	0	713
September	0	14	0	39.88	0	13
October	521	0	438	0	681	0
November	2321	0	2438	0	2395	0
December	3864	0	4027	0	4023	0

Table 53: Annual energy needs in Warsaw, year 2050

	A1B	**A2**	**B1**
Heating energy(kWh)	17952	18164	18709
Cooling energy (kWh)	2049	1680	1797
Heating energy (kWh/m^2)	95	97	100
Cooling energy (kWh/m^2)	11	9	10

Table 54: Monthly needs in Stockholm in kWh, year 2050

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	4842	0	4983	0	5154	0
February	4374	0	4232	0	4445	0
March	3045	0	3011	0	3303	0
April	1017	0	1236	0	987	0
May	0	0	0	0	0	0
June	0	266	0	254	0	252
July	0	645	0	709	0	569
August	0	317	0	214	0	215
September	0	0	0	154	0	8
October	1108	0	1079	0	1186	0
November	3250	0	3301	0	3272	0
December	4429	0	4402	0	4622	0

Table 55: Annual energy needs in Stockholm, year 2050

	A1B	**A2**	**B1**
Heating energy(kWh)	22065	22243	22969
Cooling energy (kWh)	1228	1331	1044
Heating energy (kWh/m^2)	117	118	122
Cooling energy (kWh/m^2)	7	7	6

5.2.4 Simulation results for the year of 2060

Future year of 2060 is going to be examined in this section. It is important to note that future predictions concerning the climate consist of 3 possible scenarios, which are examined below and are already analyzed in chapter 4. These scenarios are A1B, A2 and B1 and are related to uncertainty ranges.

Table 56: Monthly needs in Larnaca in kWh, year 2060

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	9	0	10	0	17	0
February	7	0	17	0	18	0
March	1	0	0	0	3	0
April	0	95	0	56	0	50
May	0	1112	0	1094	0	931
June	0	2181	0	2144	0	2020
July	0	2920	0	2919	0	2728
August	0	2904	0	2843	0	2702
September	0	2380	0	2346	0	2200
October	0	989	0	962	0	928
November	0	0	0	0	0	0
December	0	0	0	0	0	0

Table 57: Annual energy needs in Larnaca, year 2060

	A1B	**A2**	**B1**
Heating energy(kWh)	17	27	38
Cooling energy (kWh)	12580	12363	11558
Heating energy (kWh/m^2)	0	0	0
Cooling energy (kWh/m^2)	67	66	61

Table 58: Monthly needs in Athens in kWh, year 2060

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	120.937	0	79.842	0	160.296	0
February	186.026	0	196.762	0	298.236	0
March	23.211	0	25.784	0	42.853	0
April	0	2.788	0	9.929	0.753	0
May	0	916.024	0	930.477	0	738.299
June	0	2294.28	0	2292.999	0	2107.2
July	0	3370.488	0	3362.62	0	3084.388
August	0	3406.331	0	3357.431	0	3130.339
September	0	2488.983	0	2454.831	0	2339.18
October	0	883.585	0	779.653	0	721.133
November	0	0	0	0	0	0
December	6.167	0	5.613	0	26.747	0

Table 59: Annual energy needs in Athens, year 2060

	A1B	**A2**	**B1**
Heating energy(kWh)	336	308	529
Cooling energy (kWh)	13362	13188	12121
Heating energy (kWh/m^2)	2	2	3
Cooling energy (kWh/m^2)	71	70	64

Table 60: Monthly needs in Rome in kWh, year 2060

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	596	0	514	0	646	0
February	440	0	536	0	656	0
March	101	0	95	0	147	0
April	1	0	3	0	1	0
May	0	445	0	412	0	337
June	0	1554	0	1564	0	1412
July	0	2531	0	2525	0	2324
August	0	2571	0	2534	0	2346
September	0	1683	0	1691	0	1504
October	0	518	0	441	0	425
November	8	0	7	0	19	0
December	516	0	514	0	637	0

Table 61: Annual energy needs in Rome, year 2060

	A1B	**A2**	**B1**
Heating energy(kWh)	1662	1668	2106
Cooling energy (kWh)	9301	9167	8348
Heating energy (kWh/m^2)	9	9	11
Cooling energy (kWh/m^2)	49	49	44

Table 62: Monthly needs in Paris in kWh, year 2060

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	2349	0	2378	0	2466	0
February	1790	0	1980	0	2070	0
March	1055	0	1071	0	1334	0
April	32	0	286	0	269	0
May	0	5	0	0	0	4
June	0	338	0	411	0	309
July	0	1143	0	1088	0	968
August	0	1200	0	1269	0	960
September	0	492	0	467	0	428
October	31	0	35	1	42	0
November	1142	0	1159	0	1254	0
December	2207	0	2259	0	2345	0

Table 63: Annual energy needs in Paris, year 2060

	A1B	**A2**	**B1**
Heating energy(kWh)	8902	9170	9780
Cooling energy (kWh)	3178	3236	2669
Heating energy (kWh/m^2)	47	49	52
Cooling energy (kWh/m^2)	17	17	14

Table 64: Monthly needs in Berlin in kWh, year 2060

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	3787	0	3472	0	3573	0
February	2804	0	2803	0	2933	0
March	1594	0	1834	0	1844	0
April	433	0	350	0	381	0
May	0	128	0	32	0	35
June	0	462	0	503	0	444
July	0	1044	0	895	0	944
August	0	1050	0	873	0	727
September	0	162	0	220	0	212
October	179	3	89	0	372	0
November	1813	0	1849	0	2049	0
December	3144	0	3324	0	3435	0

Table 65: Annual energy needs in Berlin, year 2060

	A1B	**A2**	**B1**
Heating energy(kWh)	13755	13720	14587
Cooling energy (kWh)	2849	2523	2361
Heating energy (kWh/m^2)	73	73	78
Cooling energy (kWh/m^2)	15	13	13

Table 66: Monthly needs in Warsaw in kWh, year 2060

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	4646	0	4364	0	4737	0
February	3388	0	3453	0	3346	0
March	2261	0	2315	0	2527	0
April	719	0	528	0	602	0
May	0	98	0	43	0	25
June	0	318	0	341	0	321
July	0	986	0	871	0	861
August	0	916	0	670	0	661
September	0	125	0	122	0	55
October	424	0	367	0	505	0
November	2120	0	2337	0	2425	0
December	3731	0	3899	0	3982	0

Table 67: Annual energy needs in Warsaw, year 2060

	A1B	**A2**	**B1**
Heating energy(kWh)	17289	17263	18123
Cooling energy (kWh)	2444	2047	1922
Heating energy (kWh/m^2)	92	92	96
Cooling energy (kWh/m^2)	13	11	10

Table 68: Monthly needs in Stockholm in kWh, year 2060

	A1B		A2		B1	
	Heating	Cooling	Heating	Cooling	Heating	Cooling
January	4817	0	4823	0	5087	0
February	4073	0	4079	0	4433	0
March	3023	0	2936	0	3105	0
April	815	0	933	0	1068	0
May	0	0	0	0	0	0
June	0	403	0	254	0	290
July	0	746	0	730	0	720
August	0	248	0	229	0	211
September	0	54	0	5	0	3
October	958	0	975	0	1171	0
November	3089	0	3038	0	3197	0
December	4335	0	4272	0	4595	0

Table 69: Annual energy needs in Stockholm, year 2060

	A1B	**A2**	**B1**
Heating energy(kWh)	21109	21056	22655
Cooling energy (kWh)	1451	1217	1224
Heating energy (kWh/m^2)	112	112	120
Cooling energy (kWh/m^2)	8	6	7

5.2.5 Concentrating results for the years examined

In the following chapter concentrating results in kWh/m^2 are presented for the years of 2040, 2050 and 2060. In addition to this, diagrams are used to depict the variant situation in each city as the years pass. Final comparison is made in kWh/m^2 and not in kWh. This is important, since energy per square meter gives a more representative idea of the changing situation.

To be more specific, tables 70, 71 and 72 present the annual heating and cooling energy needs for each scenario and city in kWh/m^2 for the years of 2040, 2050 and 2060, respectively. Moreover, from diagram 3 to diagram 16, the energy analysis over time for each city is taking place. Heating and cooling needs are depicted in separate diagrams, so as the final results to be more descriptive.

Table 70: Concentrating results in kWh/m^2 for the year of 2040

	Heating energy (kWh/m^2)			**Cooling energy (kWh/m^2)**		
	A1B	**A2**	**B1**	**A1B**	**A2**	**B1**
Larnaca	0	0	0	62	60	59
Athens	3	3	4	63	62	61
Rome	12	11	13	44	43	41
Paris	53	55	56	13	12	11
Berlin	80	80	82	11	11	11
Warsaw	100	101	101	10	9	8
Stockholm	122	123	125	5	5	4

To start with, it is easy for someone to notice that the three scenarios under study provide approximately the same results. Larnaca and Stockholm are the two extreme cities analyzed regarding cooling and heating needs, respectively. Heating needs in Stockholm though are twice as much as the cooling ones in Larnaca. Specifically, heating energy in Stockholm rises up to 124.87 kWh/m^2, whereas cooling energy in Larnaca equals to 58.87 kWh/m^2, according to B1 scenario.

Table 71: Concentrating results in kWh/m^2 for the year of 2050

	Heating energy (kWh/m^2)			**Cooling energy (kWh/m^2)**		
	A1B	**A2**	**B1**	**A1B**	**A2**	**B1**
Larnaca	0	0	0	65	62	60
Athens	2	2	3	68	66	63
Rome	10	10	11	46	45	42
Paris	50	52	54	14	14	12
Berlin	76	77	78	12	12	11
Warsaw	95	97	100	11	9	10
Stockholm	117	118	122	7	7	6

The table above indicates similar conclusions as table 70, which are the increasing trend of heating energy and the decreasing trend of cooling energy as the city studied gets Northern. The comparison between tables 70 and 71 shows that climate gets warmer as decades pass by, which means reduction of heating needs and growth of cooling ones. This is apparent since now Stockholm requires 122.17 kWh/m^2 of heating energy and Larnaca 59.77 kWh/m^2 of cooling energy, according to B1 scenario.

Table 72: Concentrating results in kWh/m^2 for the year of 2060

	Heating energy (kWh/m^2)			**Cooling energy (kWh/m^2)**		
	A1B	**A2**	**B1**	**A1B**	**A2**	**B1**
Larnaca	0	0	0	67	66	61
Athens	2	2	3	71	70	64
Rome	9	9	11	49	49	44
Paris	47	49	52	17	17	14
Berlin	73	73	78	15	13	13
Warsaw	92	92	96	13	11	10
Stockholm	112	112	120	8	6	7

As the comparison of the other tables demonstrates, table 72 makes it clear that global warming is an ongoing phenomenon with overt consequences on the climate, since the heating energy required gets even more declined, whereas the complete opposite happens to cooling energy needs. In 2060, Stockholm demands only 120.5 kWh/m^2 of heating energy, while Larnaca needs 61.48 kWh/m^2 of cooling energy, according to B1 scenario.

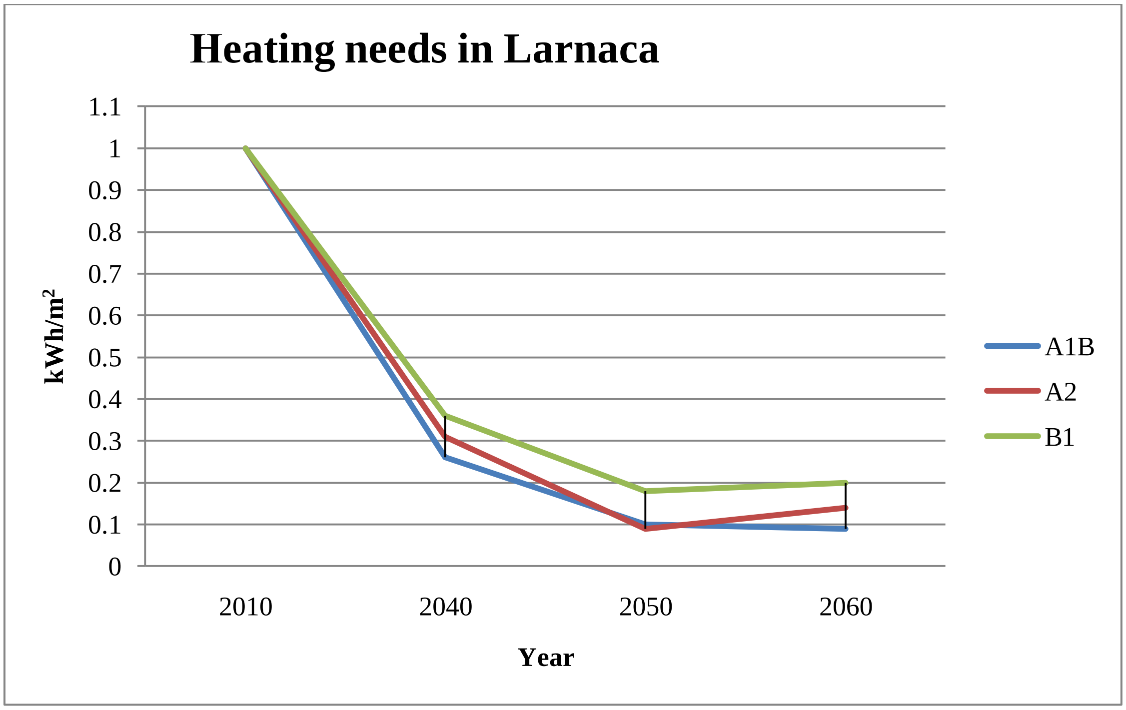


Diagram 3: Analysis in heating needs in Larnaca

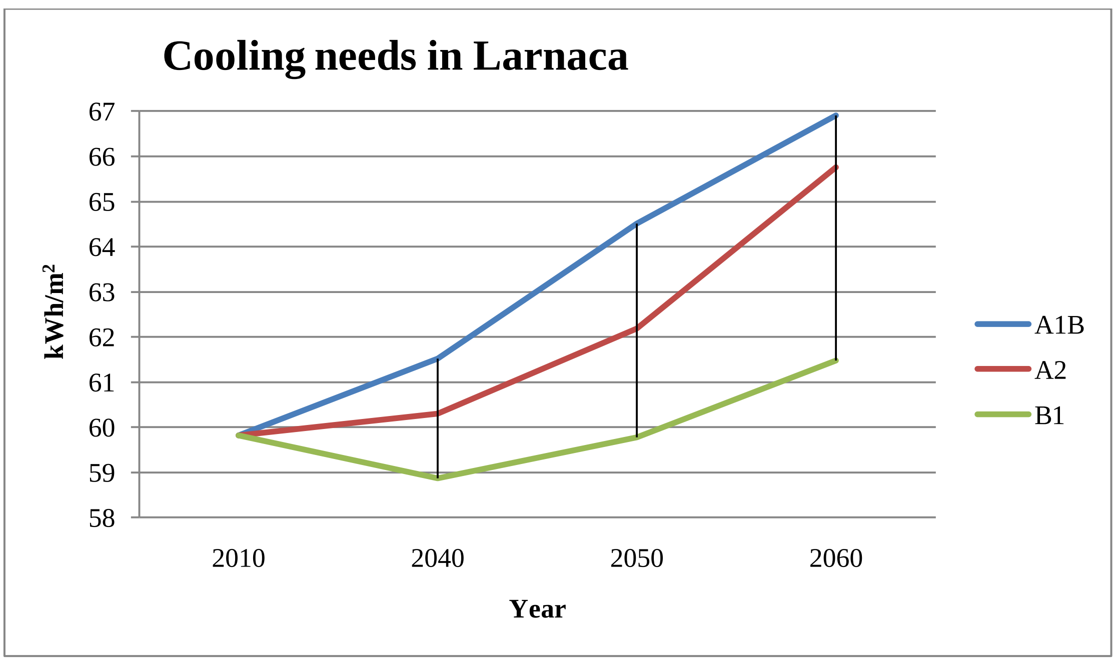


Diagram 4: Analysis in cooling needs in Larnaca

Diagrams 3 and 4 show how the city of Larnaca is influenced by climate change throughout the decades. Having already low heating energy demands, the heating needs of the city will be even more reduced approximately by 0.75 kWh/m^2 until the year of 2060. Cooling needs, on the other hand, will rise sharply from 60 to 67 kWh/m^2, according to A1B scenario.

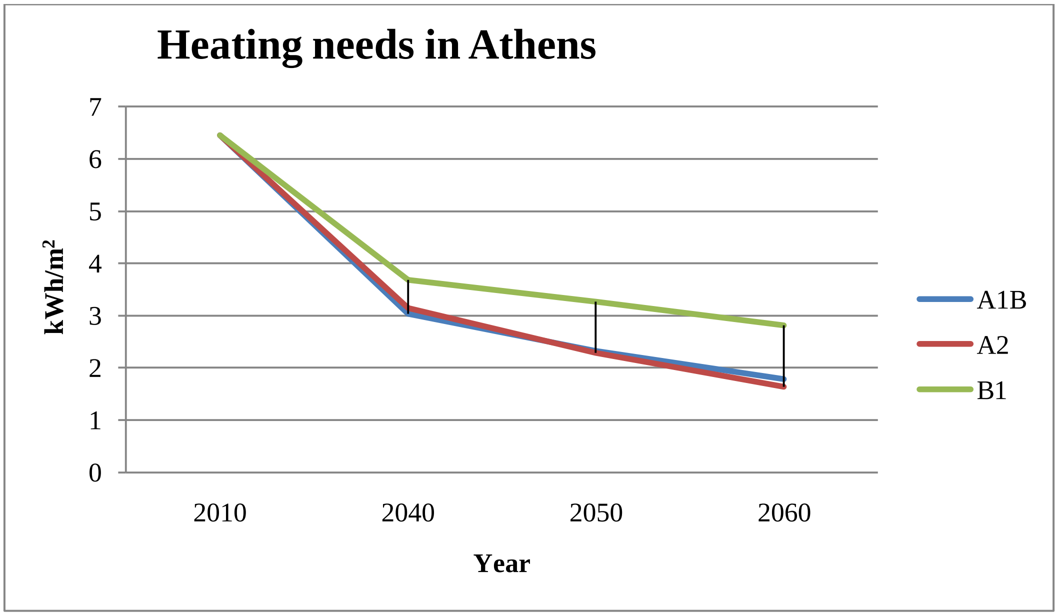


Diagram 5: Analysis in heating needs in Athens

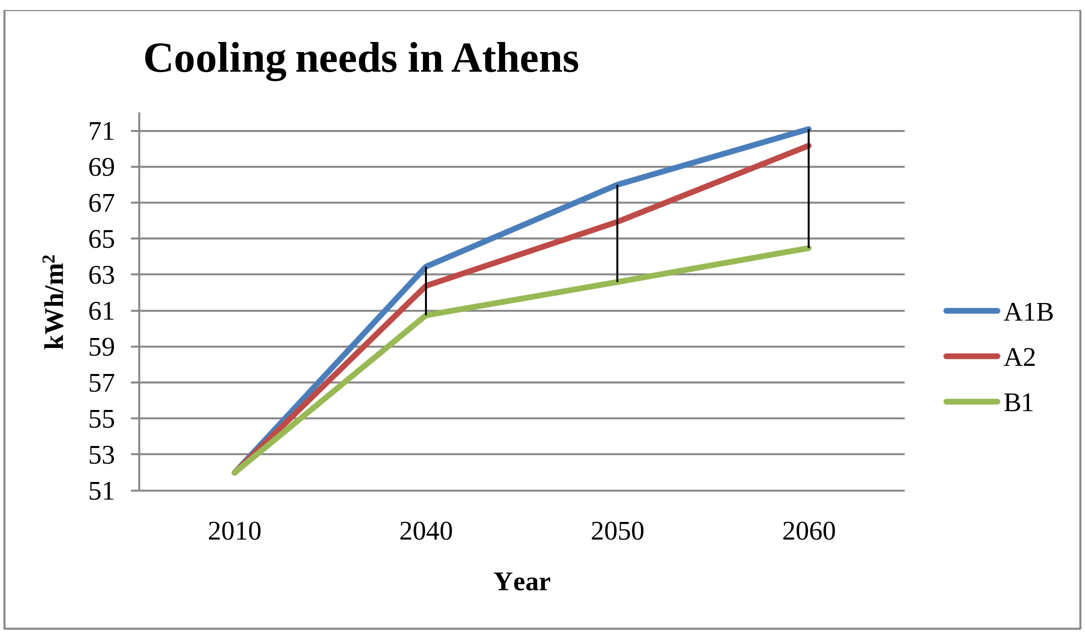


Diagram 6: Analysis in cooling needs in Athens

As Athens is located in the Southern part of Europe, its heating needs are quite reduced compared to other European cities. Until the year of 2060 there will be more depletion of its heating energy needs, approximately by 4 kWh/m^2. On the contrary, its cooling needs will exceed 71 kWh/m^2, according to A1B scenario. These results exhibit a great contrast in energy needs that concern the same city.

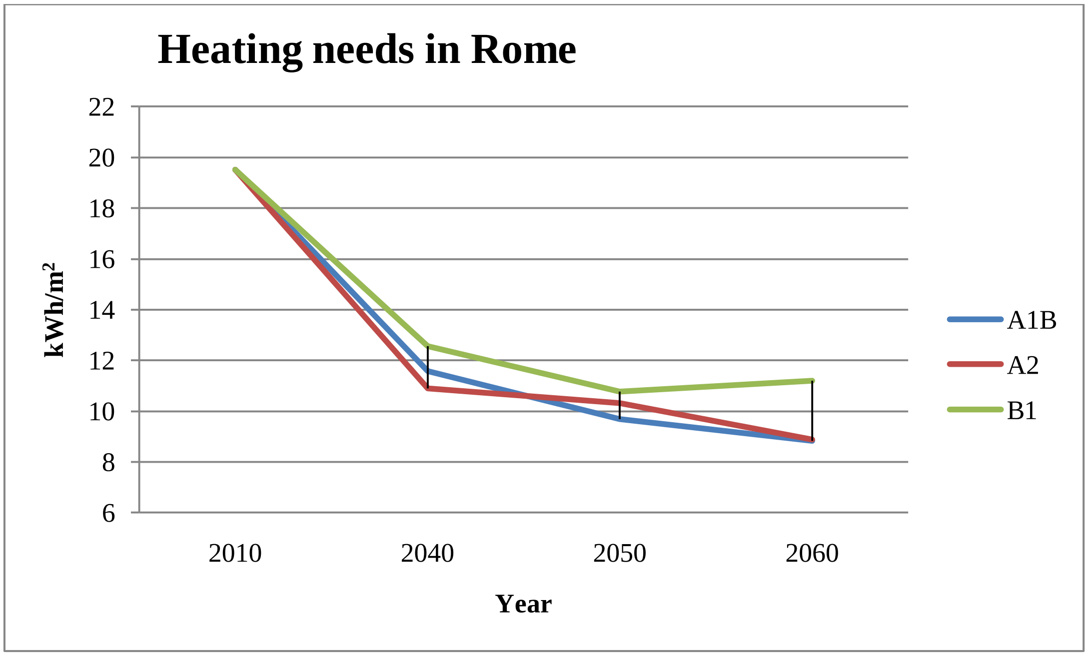


Diagram 7: Analysis in heating needs in Rome

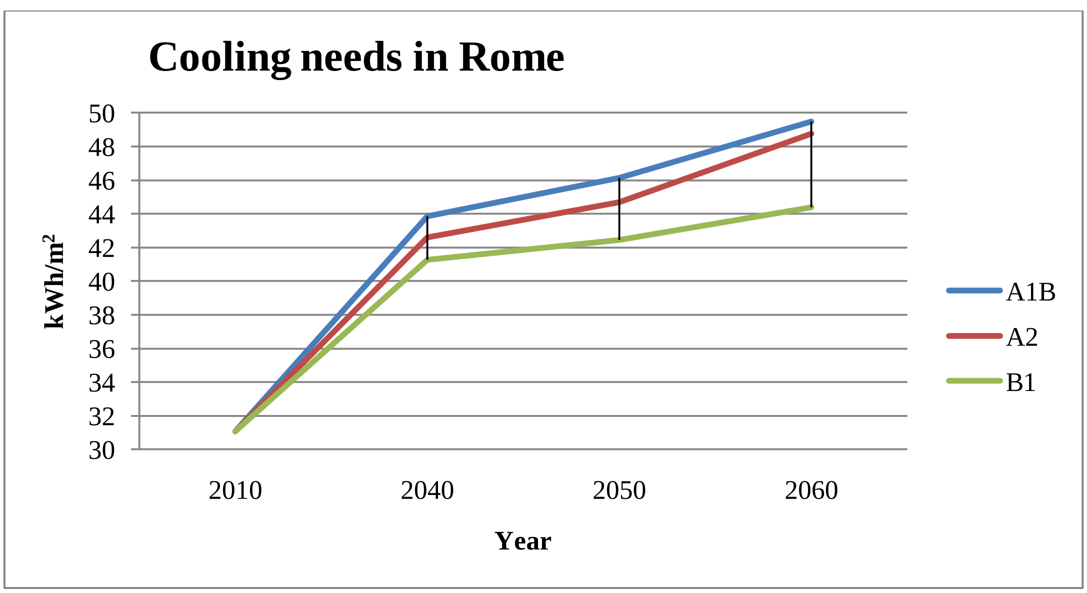


Diagram 8: Analysis in cooling needs in Rome

Diagrams 7 and 8 depict the fluctuation of heating and cooling energy needs, respectively, in the city of Rome. Rome demands, approximately, 19.5 kWh/m^2 for heating and 31 kWh/m^2 for cooling in 2010. As expected, until the year of 2060 these values alter. On average, heating needs will drop to 10 kWh/m^2 and cooling ones will rise to 46 kWh/m^2.

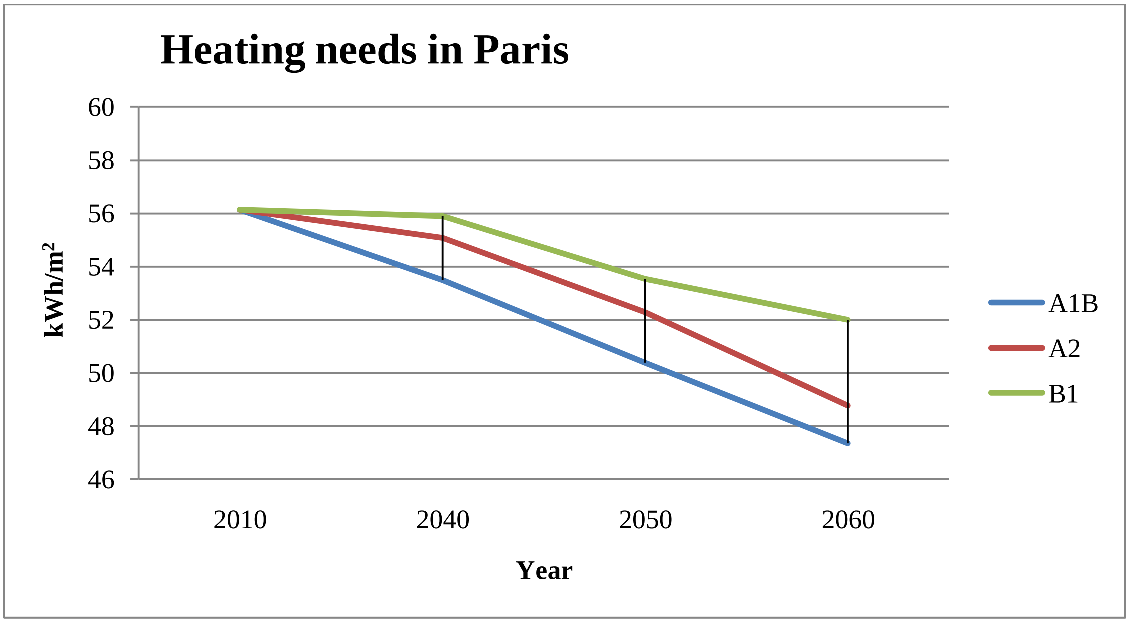


Diagram 9: Analysis in heating needs in Paris

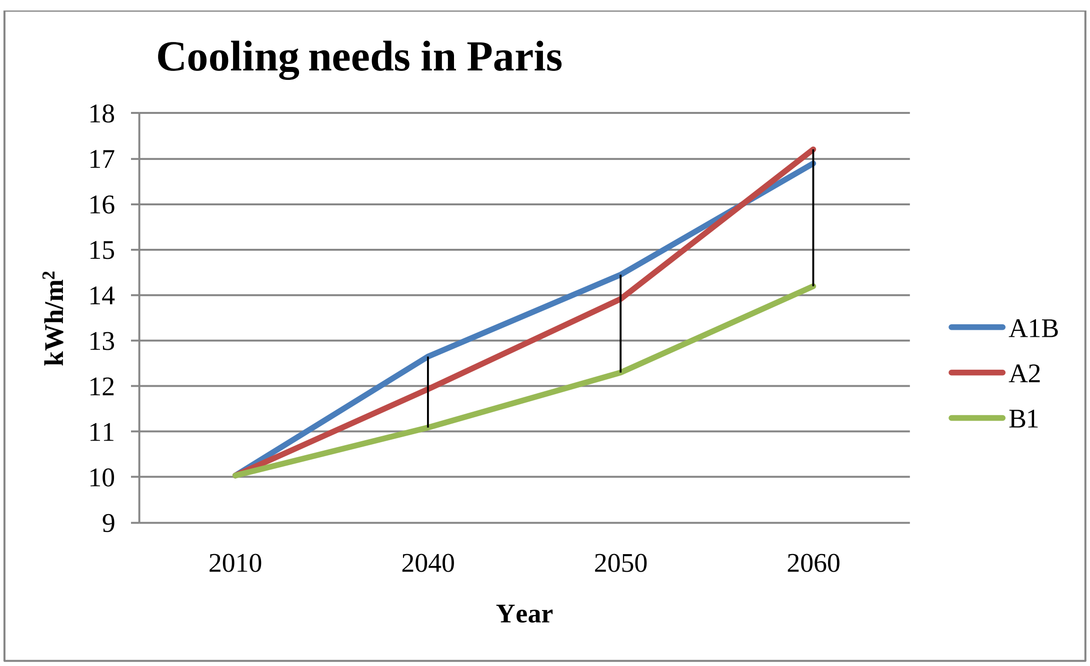


Diagram 10: Analysis in cooling needs in Paris

Paris is located in the central part of Europe and its energy analysis is depicted in diagrams 9 and 10. It is obvious that heating energy will be reduced to less than 48 kWh/m^2 by the year of 2060, according to A1B scenario. The same scenario indicates that cooling needs will be dramatically increased almost to 17 kWh/m^2.

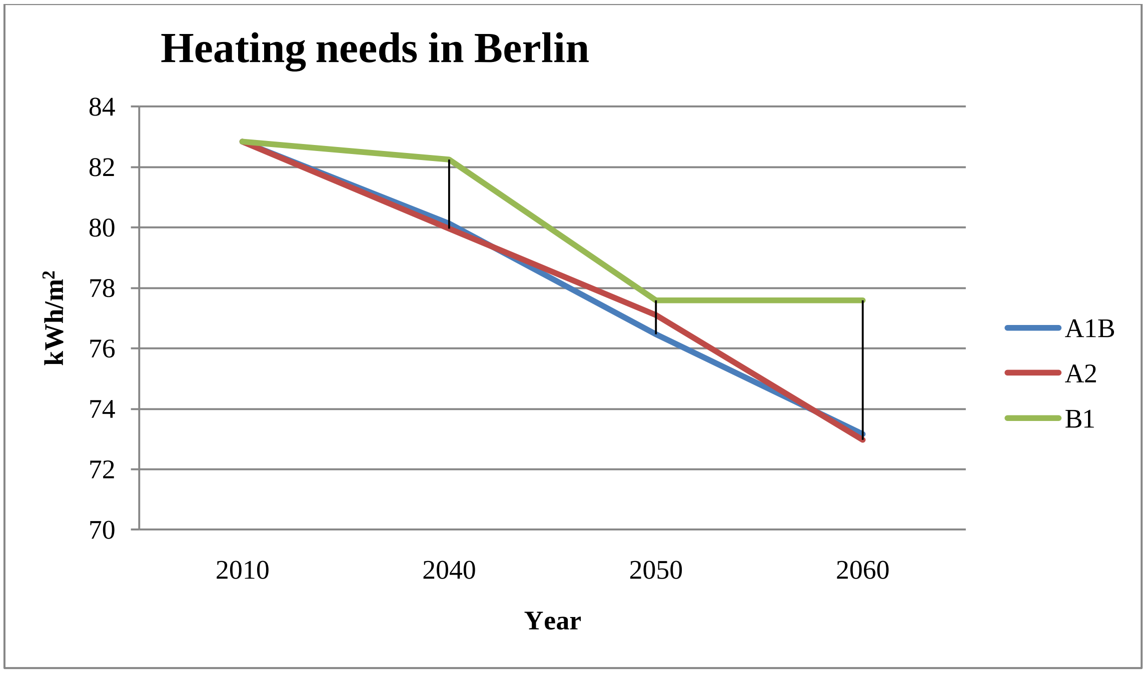


Diagram 11: Analysis in heating needs in Berlin

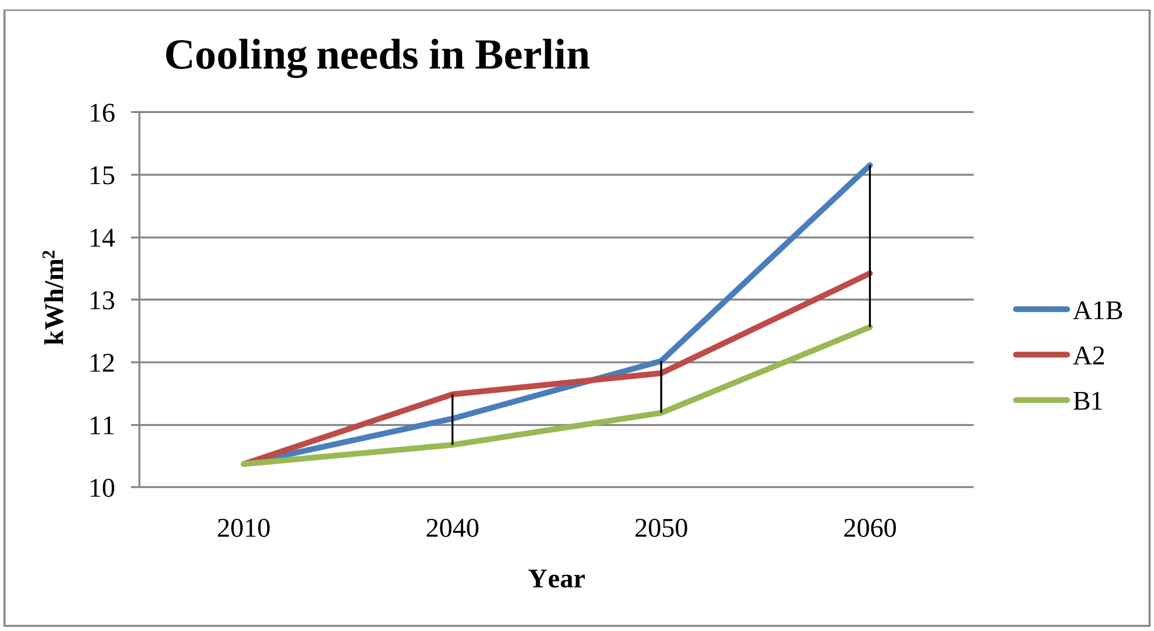


Diagram 12: Analysis in cooling needs in Berlin

Diagram 11 demonstrates the decreasing trend of the heating needs in Berlin. All scenarios depict that there is reduction of the energy needs in the city as the years pass, however B1 scenario shows that from 2010 until 2040 there is a minor decrease of the heating needs, whereas only in the decade of 2040-2050 there is a significant fall of the values. From 2050 to 2060 the pattern of the chart is steady. Diagram 12 depicts the increasing pattern of the cooling needs in Berlin with all three scenarios having almost the same morphology. A2 scenario provides more mean rates, whereas A1B scenario is the most extreme one.

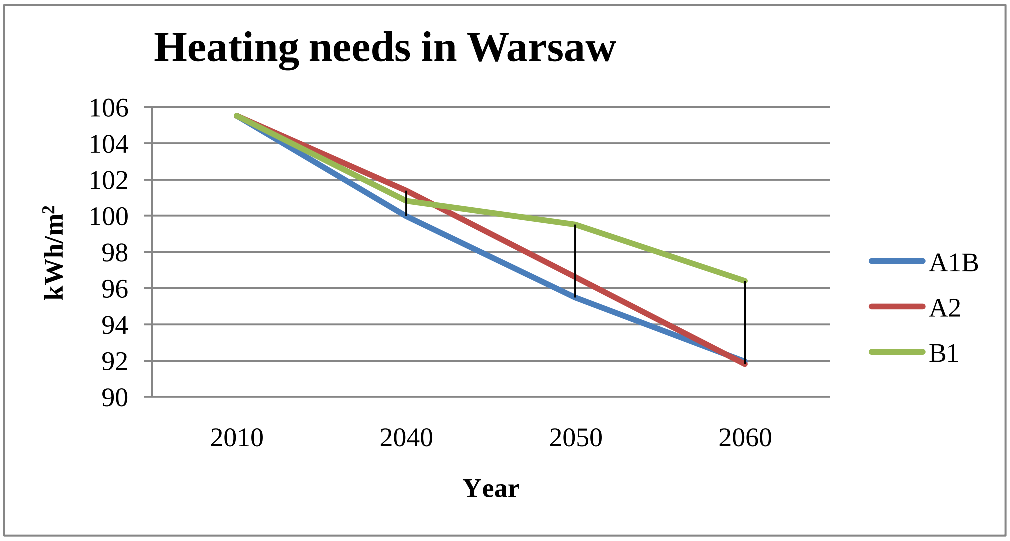


Diagram 13: Analysis in heating needs in Warsaw

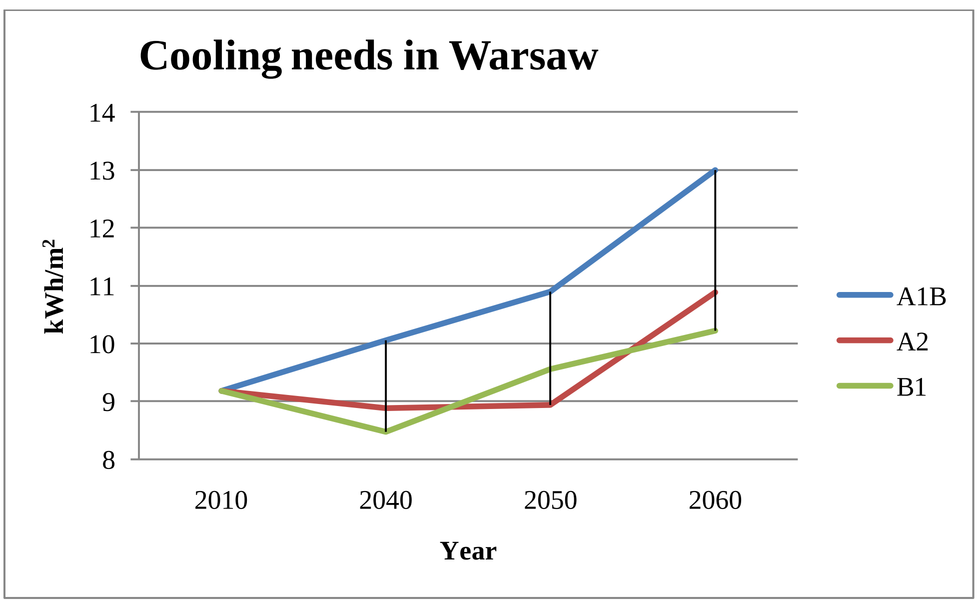


Diagram 14: Analysis in cooling needs in Warsaw

Diagrams 13 and 14 show the analysis in heating and cooling needs, respectively, for the city of Warsaw. It is clear that heating energy is strongly decreased throughout the years, however Warsaw is the least affected city as far as the cooling needs are concerned.

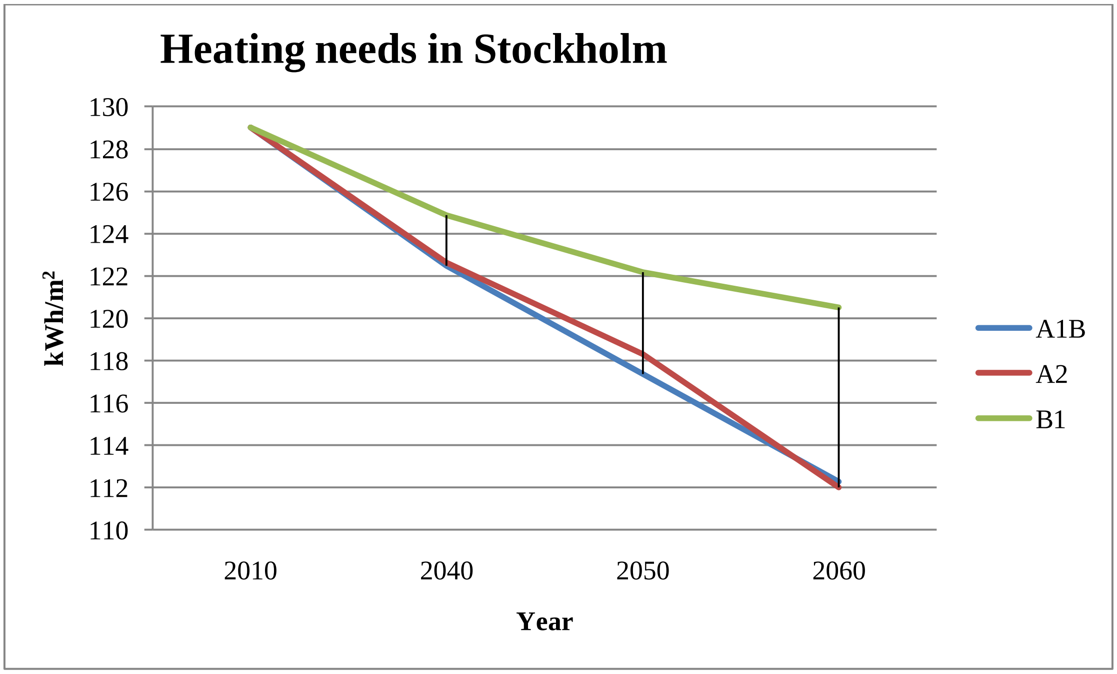


Diagram 15: Analysis in heating needs in Stockholm

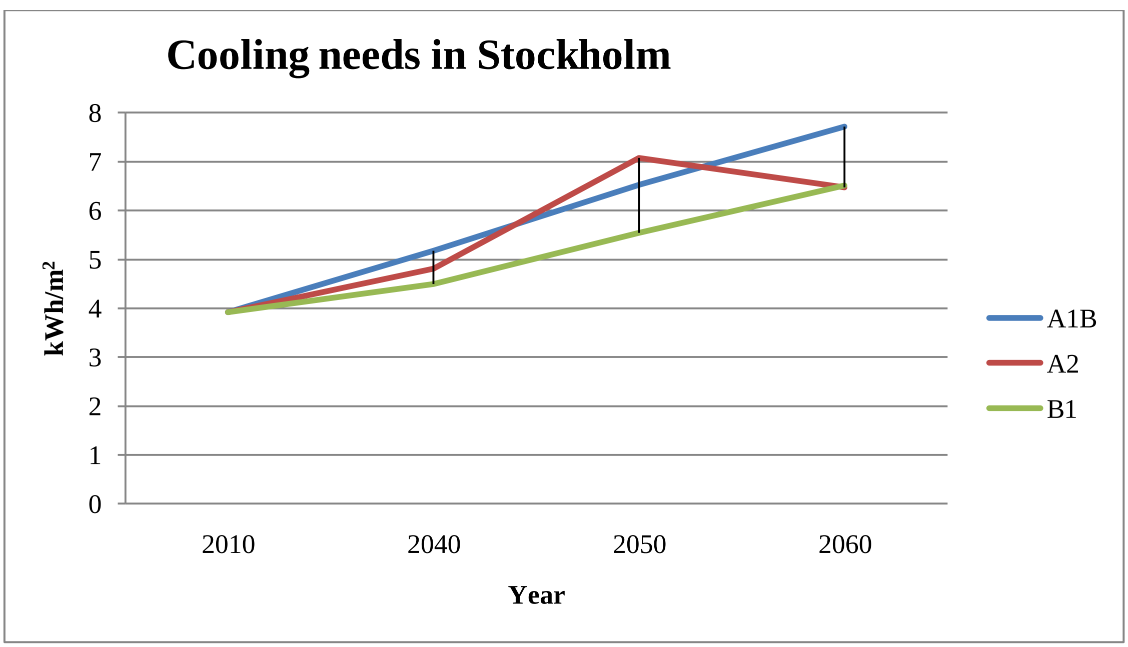


Diagram 16: Analysis in cooling needs in Stockholm

Diagrams 15 and 16 exhibit how heating and cooling energy is modified throughout the years in the city of Stockholm. It is obvious that heating needs are declining and cooling needs are increasing over the decades. This is something logical and expected for all the cities examined.

The extreme values of heating and cooling needs are going to be analyzed. These values concern the two climatically extreme cities studied, which are Larnaca and Stockholm. The highest heating needs and the lowest cooling ones are found in Stockholm in the year of 2010, since global warming offers warmth in the following decades. The highest heating needs are 129.03 kWh/m^2 and the lowest cooling ones are 3.92 kWh/m^2.

Larnaca constitutes already an extreme case of high cooling needs throughout the year. This is correct, since its cooling needs are equal to 66.91 kWh/m^2, according to A1B scenario. Hence, it is expected that its cooling needs are going to be the highest ones among all cases by the year of 2060. The same year, its heating energy needs will be equal to 0.09 kWh/m^2, according to A1B scenario.

It is noticed that A1B and B1 scenarios are those with the more extreme values, whereas A2 scenario provides more mean rates. This may be contributed to the fact that A2 storyline describes a world with not such developed technologies as the other cases.

Finally, table 73 below indicates the interesting fact of which city has been more influenced by the ongoing effect of climate change and global warming over the years. The table shows the subtraction of the values in kWh/m^2 between the years of 2010 and 2060.

Table 73: Differences in kWh/m^2 of the years of 2010 and 2060

	Heating energy (kWh/m^2)			**Cooling energy (kWh/m^2)**		
	A1B	**A2**	**B1**	**A1B**	**A2**	**B1**
Larnaca	1	1	**1 (0.8)**	7	6	2
Athens	5	5	4	**19 (19.1)**	18	12
Rome	11	11	8	18	18	13

Paris	9	7	4	7	7	4
Berlin	10	10	5	5	3	2
Warsaw	14	14	9	4	2	**1 (1.04)**
Stockholm	17	**17 (17.03)**	9	4	3	3

It is patent that the most influenced cities are Athens and Stockholm. Athens has the greatest increase in cooling needs for A1B scenario, whereas Stockholm has the greatest decrease in heating needs, according to A2 scenario. On the other hand, Larnaca and Warsaw are the least affected cities, as far as the heating energy needs and cooling energy needs are concerned, respectively.

6. CONCLUSIONS

This section is among the weightiest ones, since all final results lead to the desired outcome. The significance of the dissertation and the original goal set can be said if it is achieved or not, based on the conclusions. Questions like: "What is the difference between multi-year and freely available climatic data based simulations?" or "How do different climatic zones affect the performance of the exact same building?" can be answered now. If the role of multi-year climatic data, freely available data and climate change is semantic as far as dynamic simulation is concerned, is finally unmistakable.

To start with, all results lead to the same conclusion, which is that climate change does affect the energy consumption of buildings. No matter what the scenario (A1B, A2, B1) or the weather data (multi-year, freely-available) used is, it is apparent that heating needs face great reduction while cooling ones tend to increase as decades pass. Under these circumstances the necessity of planning depending on future climate data sets is underlined. However, engineers design basing on weather data of yesterday. This is unsafe since the life span of a building is approximately 50-100 years, something that should be taken into consideration. So, no matter what the studied scenario is, optimistic or pessimistic, the building has to be shielded with the right climatic conditions of tomorrow in order to encounter them correctly.

One thing is definitely observed as far as the various climatic data sources are concerned, which is that they offer alternative results. For the year of 2010, the deviation between multi- year and freely-available climatic data values rises to 20 kWh/m^2 in heating needs and 8 kWh/m^2 in cooling ones. The above unlike results make clear that climatic sources are uncertain.

Moreover, the results clarify that the exact same building behaves in a different way based on each climatic zone. From Larnaca to Stockholm, simulations provide dissimilar monthly heating and cooling energy values. This is logical, since Southern Europe deals with benign climatic conditions and sunny weather, whereas Northern countries front low temperatures and rough weather. The most affected cities seem to be Athens and Stockholm, which may be contributed to the fact that they are already extreme cases. By now, Athens has confronted with high cooling energy needs, while Stockholm has dealt with great heating ones.

Finally, all the above in combination with effective cooling techniques could lead to the desirable result, which is the minimum effect of the building by climate change through the decades. Passive cooling strategies, proper ventilation and smart orientation could be conducive to dealing with the problem of overheating in buildings. Another solution would be using more eco-friendly HVAC systems like a heat pump, which can be a smart alternative to a fuel boiler. Heat pumps function as air conditioners for cooling and they are considered environmentally friendly, since they use less electricity compared to other devices. Also, they are carbon neutral, therefore they do not contribute to greenhouse gases.

To sum up, climate change affects not only people's everyday lives, but building infrastructure, too. All weather data used, multi-year and freely-available, provide results that prove this influence. Hence, future climatic data must be used for better planning. Taking into consideration proper weather data simulation results and smart cooling solutions, the ongoing phenomenon of climate alteration, its effects on buildings and the energy sector are undoubtedly going to be handled.

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